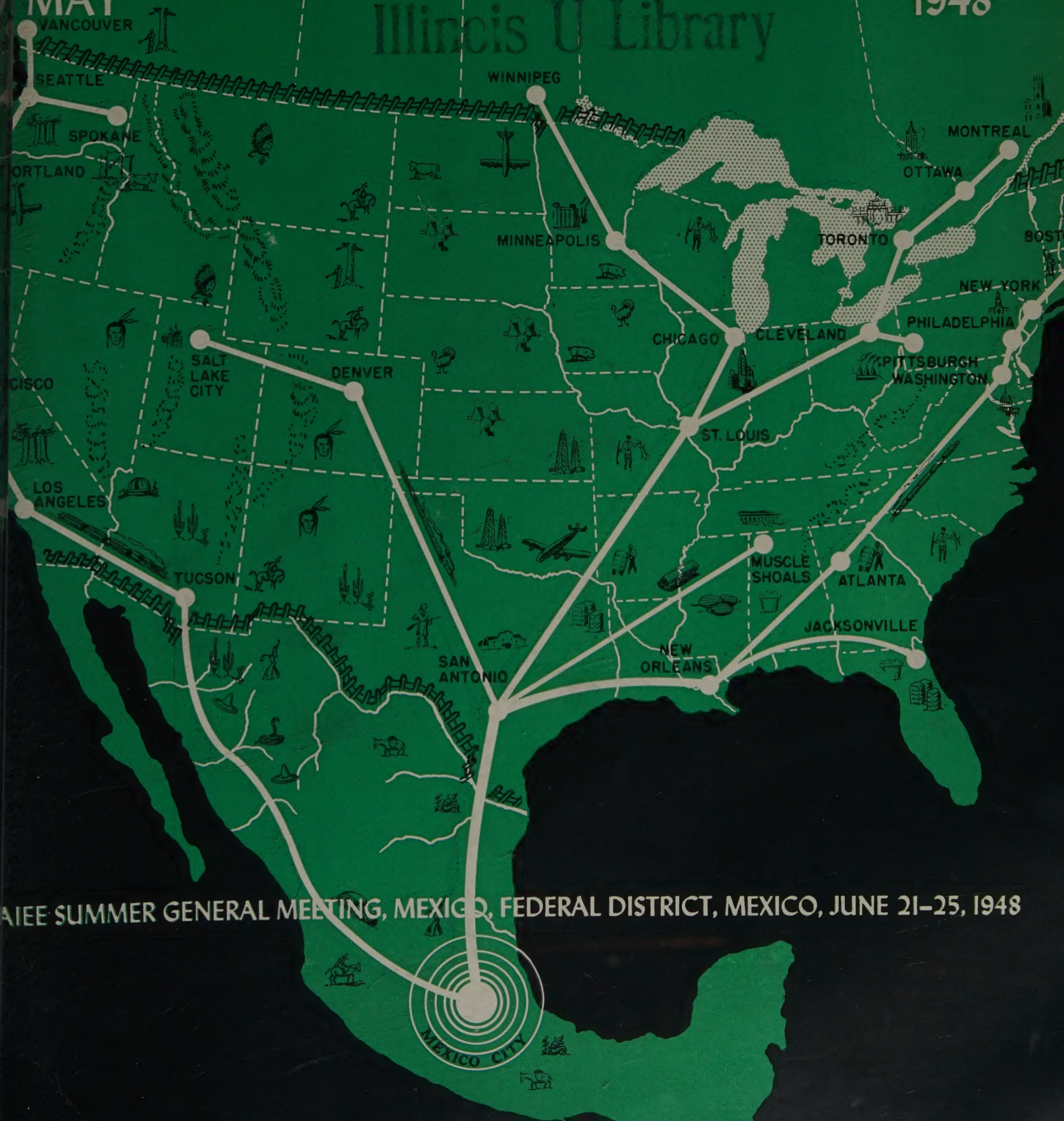
ELECTRICAL ENGINEERING

MAY 1948



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What of Air Safety?

ROBIN BEACH
FELLOW AIEE

Many of the main hazards to air safety are the result of the generation and discharge of static electricity, a problem which has not been solved satisfactorily either in commercial or military aviation. The need for constructive research in the field is apparent. However, the author submits that such dangers as arise from electrostatic discharge can be eliminated by the utilization of the ionizer described in this article.

THERE is a slogan among fliers to the effect that aviation in itself is not dangerous but, like the sea, it is terribly unforgiving of any carelessness or neglect. The slogan well could include that aviation is unforgiving of ignorance or disregard of nature's laws and, especially, of the destructive caprices of uncontrolled or unrecognized electrostatic hazards—the consideration of which is the subject of this article.

ELECTROSTATIC HAZARDS TO SAFE FLYING

Throughout the aviation industry, be it private, commercial, or military flying, outstanding hazards to safe flying are still old ones; among which are the following:

1. Radio "black-outs" still occur.
2. Radio navigation instruments still fail.
3. Airplane engines still explode in mid-air.
4. Baggage and tail compartments still catch fire or explode.
5. Tire blowouts at landing still take place.
6. From these and other causes of crashes over which they have no control, pilots still "take the rap" under the moth-eaten formula, "pilot errors."

The foregoing causes of unsafe flying and still other hazards to air safety are the result of rampant electrostatic generation on, and uncontrolled discharge from, airplanes—conditions that are becoming gravely worse with each advance in speed range of the newer and faster models. No practical means are available for reducing the generation of static electricity on airplanes in flight; but, their quiet discharge, free from radio disturbance, can be accomplished effectively by attaching a prescribed number of properly applied ionizers to the trailing edges of airfoils and propeller blades.[1] These ionizers each consist of several tufts of sharply pointed fine wire bristles of stainless steel secured to a base plate or otherwise for providing simple and convenient means of attachment.

THE ARMY-NAVY WICK

The ineffectiveness of the Army-Navy wicks seems well substantiated by almost any of the airplanes which still use them. If any appreciable reduction of radio noise were provided by them, the flight crew would be the first to insist that the wicks be maintained in properly trimmed condition; but, this does not seem to be the case. A casual inspection reveals that the discharge end of the floss which should project about one inch beyond the plastic sleeve has been dissipated to the extent that only the stubby end of the plastic covering shows. Even when the ends are trimmed properly, the adhering silver salts in which the cotton floss is dunked during manufacture soon washes off, thereby causing an open circuit insofar as permitting any ionizing discharge to occur at their ends.

Although the resistance of a wick from end to end is required to be about one megohm by the governing Army-Navy specifications, the writer has found, by measuring several hundred of them, that about 95 per cent on the average possess resistance values in the order of several hundred to many thousands of megohms.[2] Obviously their ionizing properties under these conditions are nil.

THE POLYETHYLENE-INSULATED ANTENNA

When it was found that radio black-outs still persisted on the airplanes which were using the Army-Navy wicks, attention was directed to insulating the antennas. The bare antenna wire, being of only 0.050-inch diameter and grounded to the highly electrified airplane structure at one end, constituted a relatively effective ionizer in partially discharging the airplane. However, the discharges of burst-pulse corona from the antenna wire, both by conduction and radiation, propagated shock excitations to the receivers—also creating objectionable radio interference.

During the process of converting the antenna system from bare wire to polyethylene-insulated wire, of course complicated and costly fittings had to be devised and manufactured for supporting and leading in these insulated wires, as otherwise the tiniest inadvertent exposure of the bare wire anywhere along the entire antenna system would nullify completely the intended objective. The disadvantages of the polyethylene-insulated antennas are the costly replacements and almost continual maintenance which are required, as well as their ineffectual operation. This polyethylene-insulated antenna system, as commonly employed by the air lines and the military, is used in conjunction with the wicks.

Whenever the airplanes, thus equipped with the insulated antennas and wicks, generate high electrification, even though the antennas' insulation is assumed in perfect condition at the time, uncontrolled burst-pulse corona

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Robin Beach is head, Robin Beach Engineers Associated, Brooklyn, N. Y.; associate, McCrossin and Company, Engineers, New York, N. Y.; and adjunct professor of electrical engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Figure 1. A fortuitous "happy landing" at night on a storm-swept beach after a 2-hour aimless sky cruise with continuous radiostatic black-out during a snowstorm

appears at propeller blades, edges and points of Pitot tubes, antenna masts, cotter pins, rivet burrs, cowling, and fittings, in addition to the sharp metallic trailing edges of the tip areas of wing and empennage structures where the potential gradients are many times higher than on the fuselage. Hence the antennas receive radiation from these many parasitic sources and transmit the shock excitations to the receivers, thereby still causing radio black-outs.

In addition, radio noise emanates directly from the polyethylene-insulated antennas as soon as the insulation deteriorates and punctures.[2] These punctures may develop soon after new installations are made because wide temperature cycles during flight loosen the insulation from the wires at spots along their length; and, when the ionizing potential gradients at the wires are high, destructive ionization occurs at these bare spots and also chemical agencies are formed which, together, gradually burn holes through it. Hence, the continual maintenance required to replace the punctured and deteriorated antennas becomes a costly item of operating expense.

The hapless airplane, shown in Figure 1, which narrowly and by the grace of God escaped a sea burial of its cargo of passengers, was equipped fully with the so-called antistatic devices—the wicks and the polyethylene-insulated antennas—which were and still are recommended by the Army and Navy and still are used by the air lines allegedly to eliminate radio black-outs. As a result of the ineffectiveness of these devices, the pilot was isolated from guiding aid for two hours by radio black-out during a snowstorm. Being utterly lost in the sky and almost out of gasoline from his aimless cruising, his last flare luckily illumined a beach upon which he skillfully maneuvered a safe landing.

AN ACHIEVEMENT IN PERFECTING AN AIR NAVIGATIONAL SYSTEM

A foreign agency was confronted with an interesting problem in developing a radio system of air-flight navigation wherein radio black-out caused the needles of their instruments to rotate rather than to indicate correctly at standstill the on-course position of the airplane. In trying to correct this aberration, they experimented with and tried every known means, then available, of discharging the detrimental electrification of the airplanes, including the Army-Navy wicks, all to no avail. Later, they solved their problem and preserved the utility of their navigational system by equipping the airplanes, flying by their system with sharp-pointed multiple-bristle electrostatic ionizers.[1]

THE GCA LANDING SYSTEM

The success of the ground control approach (GCA) system, now being promulgated in the United States, likewise is threatened by the communication black-outs caused by electrostatic radio interference. An airplane in approaching the airport for a landing, while it is still 30 or 40 miles away, is picked up on the screens of radarscopes which are housed with their operators near the landing strip of the field. The pilot of the approaching airplane, thereafter, subordinates his landing controls to the directions communicated to him by radio from the ground radar operators; in other words, he is "talked down to a landing." Obviously this system can be successful only insofar as the pilot can receive understandable and dependable directions.

The essential purpose of this system is to probe by radar the otherwise impenetrable atmosphere of fog or stormy weather which preclude safe landings and to direct the pilot as to safe operations in approaching the runway, levelling off, and landing his airplane. Under adverse weather conditions when ground control approach landing is needed most, electrostatic radio interference is also likely to be at its worst which may inhibit the reception of intelligible directive communications from the radar operators to the pilot. Hence, unless the electrostatic black-outs of radio noise are eliminated, the ground control approach system cannot succeed.

PROPELLER BLADES—"HOT SPOTS" OF ELECTROSTATIC HAZARDS

Another important source of radio interference originates from the electrostatic generation, discharge, and high-frequency oscillations on propeller blades. Propeller electrification is also responsible for hazards to safe flying even graver than that of radio interference.

Propellers on the airplanes of commercial air lines have blades which range variously around six feet in length. The tips move at a combined speed of rotation and translation for the different speed classifications of airplanes between approximately 400 miles per hour and 700 miles per hour. Inasmuch as, at these speeds approaching sonic value, the generation of static electricity is believed to be in the order of the fourth to fifth power of the speed, the density of electrostatic charge developed on propeller blades becomes several times greater than that on any other part of the airplane.

Because of the sharp tips and trailing edges of the propeller blades, discharges of burst-pulse corona, as sparks, more readily occur here than elsewhere on the airplane. Such impulse disturbances in themselves would cause radio interference in the nearby antennas; but these

corona impulse discharges, in addition, establish oscillations in the propeller blades wherein the blades act as complex quarter-wave antennas. If blade length alone controlled the frequency, the frequency of the oscillations would be in the order of 40 megacycles; but, during rotation, the blades undergo cyclical capacitance modulation by approaching close to the cabin or to the blades of the adjacent propeller on a 4-engine airplane which appreciably reduces the natural frequency of these free oscillations. Obviously the radio interference in the nearby antennas resulting from these oscillations introduces a source of variable high-frequency disturbances in the radio receivers. This situation at times is very serious; but, propeller electrification also introduces a more insidious danger to air safety—potential explosion hazards which are developed in the crankcases of the engines.

SPARK-PITTING OF ENGINE BEARINGS

The discharge of generated static electricity from propeller blades occurs through the oil films in the bearings of the engine in attempting to equalize its potential with that of the airfoils of the airplane. The effects of these electric discharges display themselves as spark craters, commonly, on the front thrust bearing and, to a lesser degree, on the main engine bearings. Occasionally even the rear thrust bearings show evidences of such spark blemishes. On the high-speed airplanes the propeller cone bearings literally become riddled with spark craters. Spark craters can be found commonly on such bearings in the overhaul shops of airlines. Also, shop inspectors concur in stating that these spark blemishes are worse and more frequent in winter than in summer, and that during snow flights more intense blemished conditions may develop within a single long trip, causing "rough engines" requiring immediate overhaul.

Normally the electric discharges from the propeller blades pass through the oil films of the bearings, partly as alternating current and partly as direct current. Oscilloscopic study of engines operating in test cells, after overhaul, show that the electrical resistance of the oil films is not as large as commonly believed but it is of a highly variant nature, ranging from a few ohms, at times, to several thousand ohms. The most interesting and significant behavior of these oil films is that, on occasions, instantaneous values of resistance occur in the oil films which attain almost infinite magnitudes. It is when these values of high resistance occur that the electrostatic voltage causes sparks across the oil films which pit the bearings. The deterioration of bearings from sparking is accentuated particularly near the peripheral edges of their contacting surfaces, as would be anticipated. Spark craters on a propeller cone bearing are shown in Figure 2.

Although it has not been possible for the author to undertake, alone, the complicated experimental study of investigating the nature of the electrical disturbances occurring within the moving engine parts (the connecting-rod mechanisms attached through bearings to the crankshaft) yet it seems clear that electrical oscillations occur in each of these systems consisting of the crankshaft, the connecting rods, and the piston parts which partially are insulated from the stationary structure of the engine by oil films. With the many bearings between the rear thrust bearing and the propeller, it would be difficult to account for the spark-pitting of the rear thrust bearing unless a resonant phenomenon of characteristic induced oscillations of this nature did occur as a result of the impulses applied to the moving crankcase parts from the propeller system. At this writing, however, this subject is theoretical and, perhaps, speculative; but the fact that sparks occur within the crankcase at the bearings is neither theoretical nor speculative, but is most definite and also costly to air transport operators.

EXPLOSION HAZARDS IN ENGINE CRANKCASES

It is well known that the crankcase of any internal combustion engine is filled with a flammable mixture of fuel vapor and air which escapes into it from the cylinders, leaking by the piston rings and cylinder walls during the compression and explosion cycles. Any such mixtures continually pass through localized variations of leanness and richness, both within and without the range of flammability. The explosive range for gasoline vapor lies between 1.6 per cent and 6.0 per cent by volume with air. Carbon monoxide, which also escapes from the cylinders into the crankcase, has an explosive range of 12.5 to 74.2 per cent.

Obviously a hazardous situation exists here from high-voltage sparks occurring through the oil films of the bearings within the crankcases which are pervaded with explosive mixtures. All that is required to initiate an explosion within the crankcase is the simultaneous occurrence of the two essential elements: a spark containing sufficient heat energy to ignite the explosive mixture when it occurs in an exposed location, and a fuel vapor and air mixture within the explosive range when it is exposed to the spark.

When these two basic elements occur concurrently within

Figure 2. The spark-pitting of a cone bearing which is exposed to the full electrostatic discharges from the propeller blades

In the center of the cone is shown an enlarged section of the cone-bearing surface on which can be seen the characteristic craterlike melted spots resulting from electrostatic sparks

the same space, be it in the crankcase, an explosion is inevitable. Thus the so-called "mysterious" explosions are accounted for which doubtlessly have been responsible for a number of airplane catastrophies. From such airplane wreckages sometimes scattered over an entire mountainside, the investigators are unable to give conclusive evidence, or at times even reasonable guesses, as to the originating causes of such casualties, unless they were aware of these potential explosion hazards so that propeller systems widely separated from their engines become explosion suspects.

It is the exception when an example of a crankcase explosion appears as obvious as the one which recently occurred on a "Constellation" off the coast of Florida. The loud explosion was heard by the crew and the passengers and a propeller blade pierced the cabin, killing the steward. Because of fortuitous circumstances, neither were the controls destroyed by the flying debris nor a fire started. The airplane ultimately was landed safely through the pilot's skill. Figure 3 shows where the entire propeller system with its shaft and gearing were blown out.

Obviously crankcases of airplane engines are not designed to withstand the excessive forces developed by explosions occurring within them. The end sections with the stud-connected gear housing seem to be the weakest parts as it is these which yield first and are blown off.

Such crankcase explosions are a constant threat to safe flying. It is an interesting speculation that more catastrophies from this source have not occurred. Doubtless the probability of the two essential factors required for an explosion occurring simultaneously somewhat mitigates the hazardous situation.

Laboratory tests in creating spark blemishes on bearings of much less intensity than actually were found indicate that

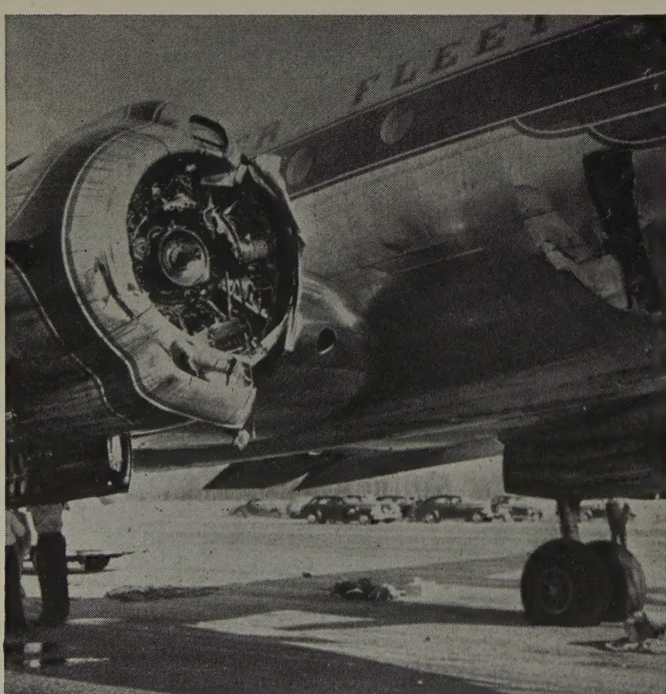

Figure 3. Another fortuitous "happy landing"—a "Constellation" in Florida after a crankcase explosion blew off the propeller system

spark energies occur greatly in excess of one joule. Rough calculations of the combined capacitance of the bearings in a double-bank engine indicate values at least in the order of 0.1 microfarad or more. As a conservative illustration, the energy in a spark at 10-kv discharge from a capacitor of 0.1 microfarad is five joules. The threshold energy required to ignite a flammable mixture of gasoline vapor and air is only 0.001 joule. A threshold ignition energy curve for benzene, as determined by the Bureau of Mines, is shown in Figure 4. Gasoline has about the same threshold ignition energy as benzene. Hence by rough but conservative calculations, it is seen that the electric energies which cause spark pitting are much more than adequate to cause the hot sparks required for igniting the explosive atmospheres in crankcases. Thus it is seen how potential explosions of engine crankcases are a real menace to safe flying.

The elimination of potential explosions within crankcases of airplane engines can be achieved readily and the author has been promulgating such safety precautions for well over a year. Rather than consider the matter lightly, simple and inexpensive expedients necessary for quickly eliminating the cause could be applied readily while, in the meanwhile, the lives of many passengers might be saved.

ELIMINATION OF ELECTROSTATIC HAZARDS FROM PROPELLERS

The electrostatic discharge of propeller blades can be accomplished in a safe, simple, inexpensive, and inconspicuous manner; and the by-passing of residual discharge current around the crankcases of engines also can be achieved easily. Thus these "hot spots" of electrostatic generation on airplanes, the propeller blades, can be rendered impotent, free and safe from their potential hazards.

Propeller blades readily can be provided with tufts of sharp-pointed bristles of stainless steel wires by mounting them on the trailing edges about 6 inches to 12 inches from the tips. They have been and are being installed in this manner on airplanes by the author for experimental operation and for life tests. Figure 5 shows such an installation on the laboratory airplane "Beta" of the Air Transport Association. The method of attaching these tufts of sensitive ionizers to a propeller blade is shown in the close-up view of Figure 6. No other type of electrostatic discharger except metallic bristles could withstand the destructive air forces caused by the high-speed tips of propeller blades. The weight of the complement of six tufts of bristles now being employed on each blade is about one gram; and, tests have demonstrated that even under the worst possible condition of thus equipping one blade only with discharge bristles for experimental purposes, there is no propeller unbalance at highest propeller speeds, on ground or in flight.

In addition, atmospheric corrosion does not occur on the stainless steel bristles and what erosive action takes place, if any, possesses the advantage of smoothing the taper of the bristles and of sharpening the points. Also, with a multiplicity of bristles in each ionizing unit and with a recommended complement of units per airplane, the discharge current from any one bristle is assured of being never more than a small fraction of one microampere. These important and basic provisions prevent objectionable electro-

etching and roughening of the points, an ionizing phenomenon which, when the total discharge current is several microamperes, destroys a single needle-point discharger within a few hours of operation.

Although such electroblemishing of single needle points does not noticeably affect the magnitude of their current discharge, it does cause them to produce objectionable radio interference. These objections have not occurred with tufted dischargers, using a large number of sharply pointed stainless steel bristles, as have been demonstrated by life tests. Several 4-tufted ionizers have been operated on life tests for about 1,500 hours of continuous discharge at excessive currents of 45 microamperes per ionizing unit without causing any measurable change in radio noise level, as determined by using a sound level meter in conjunction with a radio pickup under an ambient noise as low as 25 decibels. A microscopic examination of the long tapering points of these bristles after the completion of the life tests showed no deterioration of the points from their ionization; and, in fact, no differences in the appearance of the points could distinguish them from the points of newly made ionizers which had not yet been subjected to discharge tests.

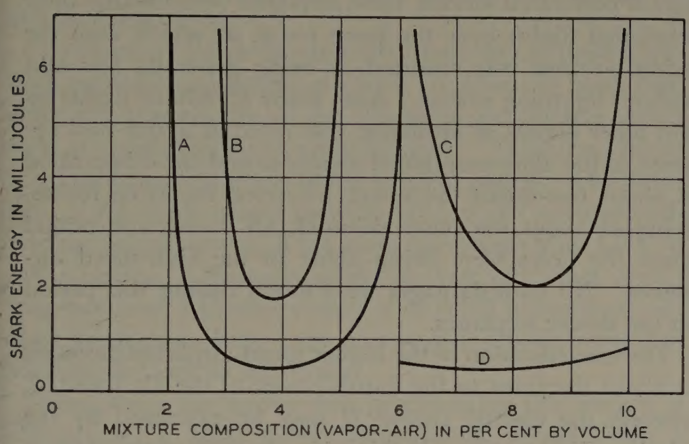

Figure 4. The threshold energies of ignition for explosive hydrocarbon fuel-air mixtures are shown to be surprisingly small

A—Benzene: 0.125-inch spheres, 0.05-inch gap
B—Benzene: 0.5-inch spheres, 0.05-inch gap
C—Natural gas: 0.5-inch spheres, 0.05-inch gap
D—Natural gas: 0.5-inch spheres, 0.10-inch gap

The by-passing of residual electrostatic currents from the propeller to the airplane structure without passing through the bearings and gearing of the engine can be achieved by a wiper system developed by the author for this purpose. Where electrically controlled pitch-changing propellers are employed, the grounding brushes on one of the slip rings may provide satisfactory conduction for the d-c component of the propeller current. However, this method does not suffice for the discharge of the high-frequency a-c component as this current flows wholly on the outer skin of the rotating propeller structure. Obviously this a-c component only could be by-passed from the propeller hub to the engine structure by surface contactors. Such a system of conduction is part of the author's safety system for the mitigation of electrification on airplanes.

However, it is important to note that, when a sufficient number of ionizers on the propeller blades are employed to reduce the voltage practically to the threshold value for ionization, no longer can burst-pulse corona sparks occur to initiate and maintain electrical oscillations on the blades. For this reason, the discharge currents from the propeller blades through the equalizing wipers to the airfoils appear as direct current.

By discharging the propeller blades in the manner described, not only are the hazardous elements of radio interference and crankcase explosions eliminated but, also, the accelerated roughening of bearings from spark pitting and the consequential premature overhaul of engines are reduced to nil. Here alone the air lines can effect material savings in costly engine maintenance simply by the installation of a few tufted ionizers on the propeller blades. Of course, the airfoils of the airplane are assumed to be equipped properly with effective discharge facilities, otherwise equally destructive discharges could occur in the reverse direction from the engines to the propeller blades likewise through the bearings in the crankcases.

POTENTIAL EXPLOSION HAZARDS IN BAGGAGE COMPARTMENTS

From time to time, "mysterious" fires or explosions have occurred in the tail sections of the fuselage on air transports which also have contributed to airplane disasters. Wherever airplane baggage is stored, potential explosion hazards come into being as a result of electric sparks from the discharge of frictional electrification of the baggage itself occurring within the space sometimes pervaded by ambient flammable atmosphere. From a broad knowledge of industrial electrostatic problems, electrification of materials of the types employed in constructing airplane luggage is a common experience.

Figure 5. The flyweight sensitive and quiet ionizers on propeller blades, assisted by others on the airfoils, eliminate electrostatic fire, explosion, radio black-out, and tire blowout hazards on airplanes, as well as premature engine overhauls from spark-pitted bearings

Let us consider the facts and conditions of such problems. The airplane luggage generally is made of plywood or composition materials with fabric coverings which commonly are impregnated or otherwise treated with protective wax coatings and preparations. In flight, the pieces of luggage undergo relative movement, sometimes in rough flights causing very considerable friction. At the high altitudes of flight, the ambient relative humidity becomes very low—almost to the vanishing point. Such conditions are particularly favorable to the generation of static electricity on the surfaces of the contacting pieces of luggage. These conditions are similar in many respects to the high electrification and brilliant sparking exhibited by clothing during dry winter weather, experiences that are within the knowledge of almost everyone.

If these baggage compartments become laden with explosive vapors from aircraft accessory power generative systems or otherwise, while electrostatic sparks are being generated, explosions are the inevitable consequence. Explosions and fires in industry commonly occur from unsuspected accumulations of explosive vapors in partial enclosures wherein electrostatic sparks from friction of paper, plastics, textiles, rubber-coated products, linoleum, waxed surfaces, and handmade products, are the igniting sources. In industry the removal of both the explosive vapors and the sources of electric sparks are essential for assuring complete safety. In baggage compartments of airplanes, the removal of the electrostatic element is difficult and costly; but, the scavenging of the explosive vapors is essentially a problem of well-designed ventilation. All hydrocarbon vapors being several times heavier than air settle into the lowest spaces and, hence, adequate ventilation should be provided while carefully avoiding any sheltered zones.

PERFORATIONS OF AIRFOILS

Another strange and dangerous behavior of static electricity on high-speed commercial transports exhibits itself in melting holes in the aluminum airfoils near the wing and stabilizer tips. These holes range from the size of a dime to more than that of a dollar bill. Such conditions were observed by the author on an airplane while measuring it for the installation of a complement of his bristle ionizers. Some of these holes in the airfoils were in areas close to the attachments of the Army-Navy wicks to the wings and empennage. If the wicks had been effective electric dischargers, holes in the airfoils should not have developed near them. It was this conclusion that first prompted the author to measure and discover the ultrahigh resistance of wicks, and to find them to possess practically open-circuit and resultant nonionizing characteristics.

Several other commercial transports of this high-speed type were inspected at the same time and place, and similar perforations of the airfoils were found on each of them. Similar conditions of perforations are reported as occurring repeatedly on these highest speed commercial airplanes. These perforations from spark-burned holes occur on the main airfoils directly adjacent to the gasoline tanks which are located within the wing structures. Obviously the hazards of fires and explosions within the wing enclosures from these potential sources of ignition near the fuel tanks are a constant threat and a serious jeopardy to safety in flight. A number of such airplane casualties were reported even while this article was being written. Furthermore, when the airfoil and control surfaces thus become injured, they need only to jam the controlling mechanisms to cause another "mysterious" and inexplicable crash landing.

The cause advanced in some quarters for the occurrence of these melted holes in the airfoils was lightning currents and, at first glance, this would seem a reasonable and logical explanation. However, the facts discredit this hasty conclusion. During the period immediately before these findings of perforated airfoils, these airplanes were making their scheduled flights over the same route, at which time the flying weather was reported as being generally fair and without lightning storms. Also, many scheduled flights by two other classes of airplanes, one rated at about half the speed of the afore-mentioned airplanes and the other rated at about two-thirds the speed, traversed the same routes, flying at about the same altitudes, all during the period when the holes were being made in the high-speed airplanes. No such damages were found during this period on the slower airplanes.

The electrification of the higher speed airplanes increases as about the third to the fourth power of the air speed, S, wherein the electric charge Q may be expressed by the relationship $Q = kS^n$. On this basis, the ratio of the generation of static electricity on the higher speed airplanes referred to that on the low-speed commercial airplanes, as unity, is given by the following table:

	Airplane Speed				
	Low Speed	Medium Speed		High Speed	
Speed ratio	1	1.45		2	
Exponent of speed—n		3	4	3	4
Electrification ratio	1	3	4.5	8	16

From this it is seen that the electrification which might be generated on the high-speed airplane in comparison with that generated on the low-speed airplane for the same atmospheric charging conditions ranges between 8 and 16 times more. Under rapid variations in the shifting of these charges from one wing tip to the other or fore and aft, such as flying at high speed suddenly in and out of electric induction fields from highly charged zones, large currents can result. Destructive high-potential sparks readily may discharge from the areas at wing or stabilizer tips where rivet burrs, for example, might initiate the discharge.

Whatever the causes may be for these melted perforations in the airfoils, the fact remains that they introduce extraordinary hazards to safe flying. In view of the facts, immediate steps should be taken to determine ways and means of permanently eliminating such hazards. The manufacturers of the airplanes are not without responsibility in conducting investigations into these hazardous conditions on the airplanes which they are selling to commercial air lines, airplanes that are being used as public carriers and which subject the public to undue risk and danger in air transit.

The failures and blowouts of tires when airplanes land also reap their harvests of crashes and holocausts. Electric

sparks up to four feet in length, under conditions favorable to electrostatic generation, have been measured between the airplane and earth just prior to landing. Potentials on the landing airplane of well over a million volts are required to cause sparks of this length. The disruptive effects of such high potential discharges from and upon the rubber, especially when it is in the form of tires under stresses of inflation, should not be unknown to the tire manufacturers. Even the tires on automotive vehicles[3] rapidly have been deteriorated and punctured by ionization, ozone and acid formations, and localized heating from current discharges under electrostatic stresses of only 10,000 to 20,000 volts from the chassis to earth.

To illustrate the destructive effects on tires of these ultrahigh potentials on airplanes which are about to land, consider the magnitudes of the discharge parameters which exist at a one million volt electrification. The energy in the spark discharge is in the order of 1,500 joules. The duration of the spark ranges between 10 and 100 microseconds and the initial current in the spark may range from 1,000 to 100 amperes. Obviously sparks of these intensities constitute miniature lightning strokes of no small proportions and their deleterious effects upon tires provide a basic element of vital importance to safe flying.

Even while the author was proofreading this section of the article, a radio news commentator reported that a 4-engine air liner, while landing at Logan Field, "blew all four tires on its double wheels." Unlike a number of others, here no serious consequences ensued. Forty-eight hours later, another single tire blowout occurred while landing. The all too frequent catastrophies from this cause can and should be eliminated. Thus far in aviation development, this element has received neither consideration nor, to the author's knowledge, even mention in aviation literature on safety.

It is interesting to note that for tires there are no simple routine tests available whereby the electrostatic deterioration of the rubber can be ascertained directly on the mounted tires. Hence, it is the more reason for eliminating the cause of this form of deterioration. The only encouragement here is to look forward to the day when operators eventually will provide their airplanes with really effective electrostatic dischargers so that tire failures from electrostatic causes thereafter will become nonexistent. The sharp-pointed ionizers, when provided in full complement on airplanes, not only will attain this worthy achievement in air safety, but likewise will mitigate the currently present electrostatic hazards of "rough-engine" flying resulting from spark-pitting of bearings, of crankcase explosions, of fires and explosions within wing and other enclosures containing inflammable fuel–air mixtures, of blackouts of radio reception, and of aberrations of radio navigational instruments.

NEED FOR CONSTRUCTIVE RESEARCH

If the art of aviation is to progress into the higher speed ranges without continuing unnecessary sacrifices of life and property, a thorough and constructive program of research and development on the elimination of hazards of static electricity on airplanes becomes essential. The manufacturers apparently are not undertaking the scientific and technical investigations required to incorporate safety designs and proper equipment to eliminate electrostatic hazards on the airplanes which they sell to the air lines, and thus the air lines must assume the responsibility of completing the design of such airplanes to make them safe to fly.

Figure 6. A close-up view showing an accepted method of attaching individual tufts of stainless steel ionizers to the trailing edge of a propeller blade near the tip

However, in view of the expense of undertaking an elaborate program of research directed toward the investigation of these highly specialized electrostatic problems, neither the manufacturers nor the air lines at present are equipped financially or with the qualified personnel to assume the burden of such a project. Of course small subdivisions of the entire electrostatic control program could be undertaken under the capable leadership of an authority in electrostatic science and technology so that continuing steps of definite and planned progress could be made.

With the vistas of the speed spectrum in aviation and guided aircraft now probing into the supersonic realms, the complexities of electrostatic phenomena have multiplied many fold. No one person nor any one organization at present is endowed with the omniscient powers of knowledge and specialized experience to provide the composite solutions to all of these problems in the field of electrostatics. Intelligent research and persevering endeavor, under the auspices of qualified and organized facilities, are required to cope with these mounting barriers to safety and control in the flight of high-speed aircraft.

If this article contributes, even in a small way, toward the awakening of those who are responsible for safety in flying to the increasing complexities and multiplication of the consequential electrostatic hazards and problems which are shrouded in the rapidly progressing frontiers of high-speed air transportation, the author shall feel that his efforts in this behalf have been well worth while.

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Induction Motor Leakage Reactance Calculations

AN AIEE COMMITTEE REPORT

Seven outstanding engineers in the field of motor design were asked to calculate by their particular method the reactances of a 2-horsepower squirrel-cage induction motor. These results are compared with test data and comments from the engineers presented.

LEAKAGE REACTANCE is of fundamental importance to induction motor designers. The basic performance of the motor, maximum torque, and locked rotor amperes are determined directly by the leakage reactance. Ability to predict accurately from calculations the leakage reactance and resulting performance is the daily problem of induction motor designers.

Over a period of nearly 50 years there have appeared in the AIEE literature and in textbooks the contributions of a number of authors dealing with various aspects of the problem. How have practicing motor designers in their working design procedures resolved this problem and how well are they able to match their design calculations to motor test performance?

The technical program committee for the AIEE Middle Eastern District technical meeting, Dayton, Ohio, September 23–25, 1947, decided to find the answers to these questions. Accordingly, arrangements were made for a motor to be built and tested. Design data, but not test results, of this motor were made available to a group of motor designers. These men, in turn, calculated the motor performance and made available their complete calculations. The results of the motor tests were set forth in an unpublished paper by A. L. Poliquin (M '43) and A. S. Bickham (A '46). Extracts from this paper are presented in this article along with the calculation results. It has been edited by a committee of the design engineers who participated.

MOTOR DESIGN DATA

The motor is a squirrel-cage induction motor rated at 2 horsepower, 220 or 440 volts, 3 phase, 60 cycles, and 4 poles. It was manufactured by The Brown Brockmeyer Company, Dayton, Ohio.

Core dimensions are given in Figures 1 and 2.

The stator windings contain 34 turns per coil. The coil span is from slot *1* to slot *8*. Number 18 heavy Formvar wire is used. A single-circuit Y connection is used for 440 volts. The measured resistance is eight ohms between terminals at 440 volts and 25 degrees centigrade.

The rotor winding consists of 0.25-inch diameter copper bars and two 0.25-inch diameter end rings welded as shown in Figure 3.

The laminations are Manelee or Allegheny electrical sheet steel, not core-plated or annealed.

TEST RESULTS

Test data are presented here in curve form only (Figures 4–8). The results of the calculations are compared in Table I.

DISCUSSION

P. L. Alger. Believing that the new formulas for zigzag reactance given in H. R. West and my paper[1] are correct, I conclude that the formulas I have been using in the past for end leakage reactance are too low. This is borne out by the fact that applying these formulas to the test motor gives a total unsaturated reactance of 11.5 ohms, or 13 per cent lower than the test value, and a value of 11.0 ohms for the saturated conditions, or six per cent lower than test (Table I). I believe it is quite feasible to develop a formula for coil end leakage reactance that is dimensionally correct and more accurate than any formulas so far published, and that it is also quite feasible to develop adequate formulas for the effects of saturation.

It is interesting to note that the value of locked rotor reactance necessary in the equivalent circuit to check the test values of 17.75 foot-pounds breakdown torque is closely 15.0 ohms, or 13 per cent more even than the unsaturated

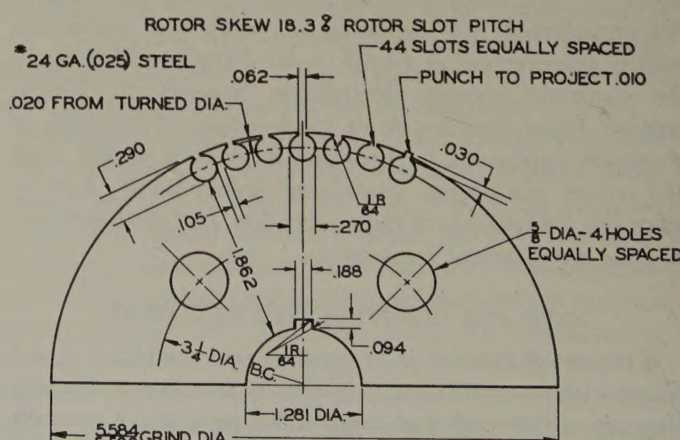

Figure 1. Rotor lamination

This report of the subcommittee on induction machinery of the AIEE rotating machinery committee was presented at the AIEE Middle Eastern District meeting, Dayton, Ohio, September 23–25, 1947, and was prepared by E. C. Barnes (A '41) of the product engineering department of the Reliance Electric and Engineering Company, Cleveland, Ohio. The introductory paragraphs were contributed by W. R. Hough (M '41) who is chief engineer of the Reliance Electric and Engineering Company. The committee consists of P. L. Alger (F '30) staff assistant to vice-president in charge of design engineering, General Electric Company, Schenectady, N. Y.; E. C. Barnes; B. M. Cain (M '46) engineering assistant, General Electric Company, Lynn, Mass.; W. H. Formhals (M '44) design engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa.; T. C. Lloyd (M '46) chief engineer, Robbins and Myers, Inc., Springfield, Mass.; L. M. Nowacki (M '45) assistant section engineer, induction motor division, General Electric Company, Schenectady, N. Y.; and P. H. Trickey (M '36) chief engineer, Diehl Manufacturing Company, Finderne, N. J.

Table I. Calculated Leakage Reactance

Motor Constants in Ohms Per Phase Y on 440-Volt Connection at 60 Degrees Centigrade

	Test	Calculated						
		PLA	ECB	BMC	WHF	TCL	LMN	PHT
Locked rotor reactance,								
Slot leakage		4.10	4.81	4.01	4.60	4.84	4.02	4.22
Coil end leakage		3.66	4.10	3.66	4.11	3.96	3.94	2.95
Zigzag leakage		3.64	4.22	3.74	5.08	4.32	4.78	3.79
Skew leakage		0.10		0.11	0.11		0.10	0.12
Other								1.43
Total reactance at full load current	13.2	11.5	13.1	11.5	13.9	13.1	12.8	
Total reactance at full voltage	11.7	11.0			12.7			12.5
Magnetizing reactance	219		215					
Magnetizing reactance, air gap only	238	252	273					246

PLA—P. L. Alger
ECB—E. C. Barnes
BMC—B. M. Cain
WHF—W. H. Formhals
TCL—T. C. Lloyd
LMN—L. M. Nowacki
PHT—P. H. Trickey

value of 13.2 ohms given by the impedance test. Because the current at breakdown is about 70 per cent of the starting value, the reactance at this point might be expected to be about 12.2 ohms, 0.70 of the way between the unsaturated and saturated values of standstill reactance, of 13.2 and 11.7 ohms, respectively. That is, 23 per cent has to be added to the test value of locked rotor reactance at the same current to check the actual breakdown torque. This difference may result from load losses that reduce the shaft torque below the torque actually produced; it may result from "deep bar effect," or the increase in inductance because of the rotor currents seeking lowest resistance instead of the lowest reactance, paths, as the secondary frequency decreases; or it may result from various errors in test or calculations, or to some combination of these.

The deep bar effect in double squirrel cage motors causes a large increase in reactance as the motor speeds up. Theory indicates that the increase is at least equal to the excess of locked rotor resistance over the rotor resistance corresponding to full load slip.[2] For the test motor, however, the value of secondary resistance indicated from the full load slip test is only three per cent lower than the value indicated by the watts input on full voltage locked rotor test, so that this is not the cause of the observed discrepancy in maximum torque. The greatest increase in running reactance that could be accounted for in this way from the test results would be to add the difference between the 25- and 60-cycle impedance values of secondary resistance, or 0.3 ohm, to the total reactance. This only will account for $2^1/_2$-per-cent reduction in breakdown torque.

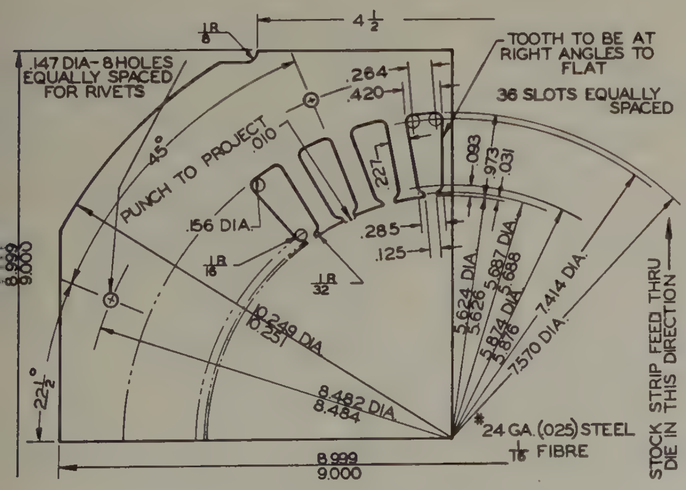

Figure 2. Stator lamination

It is likely, therefore, that the observed difference in breakdown torque results from the presence of stray load losses. To account for the total discrepancy of 23−2.5,

Table II. Values of Secondary Resistance

Ohms Per Phase Y on 440-Volt Connection at 60 Degrees Centigrade

	Ohms	Ratio
From watts input on 60-cycle locked rotor test	4.82	1.00
From torque measured on 60-cycle locked rotor test	4.14	0.86
From 60-cycle impedance test	4.51	0.94
From 25-cycle impedance test	4.20	0.87
From full load slip (neglecting stray load loss)	4.70	0.97
Calculated from drawing dimensions, Figure 3	3.54	0.74
Calculated using bars $3^5/_8$ inches long, and two 0.25-in. diam. wires per ring	4.68	0.97

Primary resistance was taken as 4.54 ohms throughout, and all tests assumed to be made at 60 degrees centigrade copper temperature. Measured winding temperature by thermocouple on tests ranged between 50 and 60 degrees centigrade.

or 20 per cent in the apparent reactance (15-per-cent reduction in breakdown torque), it would be necessary to have a load loss at the breakdown point equivalent to 2.8 pound-feet torque.

The total stray load losses at the breakdown speed of 1,400 rpm are, therefore,

$$\frac{2.8(1{,}800)(746)}{5{,}250} = 720 \text{ watts}$$

of which 240 watts represents the slip loss incurred in producing the load loss torque.

If the stray load loss torque is assumed to be proportional to the square of the current, the losses at full load will be roughly

$$720\,\frac{2.75^2}{11} = 45 \text{ watts}$$

as the current at full load is 2.75 amperes, and a breakdown is 11 amperes, approximately.

Actually, the load loss watts for a given current increase more rapidly than the speed, so that the actual stray load loss is probably of the order of 60 to 70 watts, if the 720-watt figure is correct at the breakdown point. This corresponds to a loss of between 3 and 4 points in efficiency.

Table II shows that the actual locked rotor torque of the motor is only 86 per cent of the value indicated by the watt losses in the secondary, corresponding to a loss in torque at standstill of 2.2 pound-feet. Prorating the 2.8 pound-foot load loss torque at breakdown to the 17-ampere current at

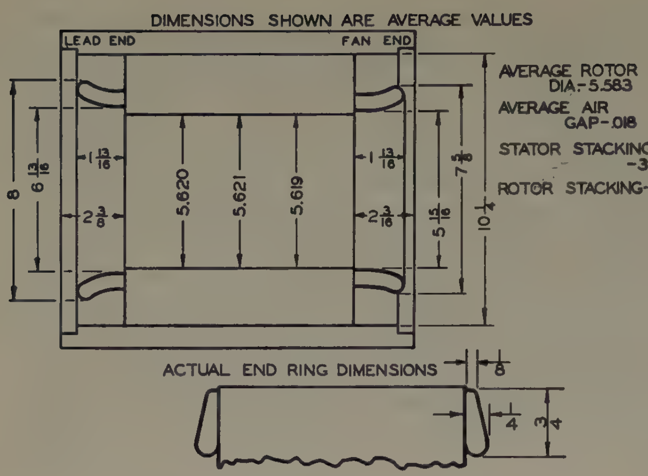

Figure 3. Stator and rotor dimensions

starting gives an indicated total torque of the harmonic fields at standstill equal to

$$\frac{17^2}{11} \times 2.8 = 6.7 \text{ pound-feet}$$

This value of 6.7, together with the observed deficit of 2.2 pound-feet at standstill, indicates that the forward harmonic torques at standstill are 2.25 pound-feet, and the backward harmonic torques are 4.45 pound-feet, which are not unreasonable.

Taking the dimensions of the squirrel cage as given on the sketches in the paper, with a bar length of 3 inches, and a ring section of 3/4×3/16, the calculated secondary resistance on the 440-volt connection is 3.54 ohms at 60 degrees centigrade, or 23 per cent less than the value indicated by the full load slip. However, if the resistance is calculated on the basis of the design data, that is, $3^5/_8$ inches long, 1/4-inch diameter copper bars, and rings formed from two 1/4-inch diameter copper wires on each end, the result is 4.68 ohms, which checks exactly the full load slip value.

Table III. Additional Values Calculated by E. C. Barnes

	Calculated Value	Test Value
Currents at 440 volts, amp		
Magnetizing	1.18	
Full load	2.75	
Locked rotor	17.0	
Torques, per cent full load torque		
Starting	225	
Pull out	350	
Performance		
Efficiency, per cent	85	
Power factor, per cent	84.4	
Speed, rpm	1,738	
Losses		
Stator I^2R	103	100
Rotor I^2R	55	62
Core	55	116
Friction and windage	30	28
Stray	30	77
Total losses	273	383
Resistance, ohms		
Stator, per phase at 60 C	4.55	
Rotor, per phase at 60 C	3.66	
Effective rotor resistance	4.40	

This difference between the two calculated values is probably the result of the welding process employed in forming the end rings, resulting in some oxide inclusions and variations in the actual as compared with the design dimensions.

Table II gives eight different values of secondary resistance observed by these various methods of test and calculation. As indicated, the 10 per cent higher value of resistance indicated by the slip test than by the 25-cycle impedance test confirms the presence of stray load losses which increase the slip under load above the value indicated by the equivalent circuit calculations.

E. C. Barnes. Besides the calculated values of reactance given in Table I, I have calculated the additional values shown in Table III. The calculated values (ohmic and effective) of secondary resistance appear too low compared with the values derived from test data. This I attribute to the somewhat indefinite cross section of the end ring. If the additional section of the end ring resulting from the weld build-up were neglected, and the ring assumed to be composed of only two 1/4-inch diameter copper bars, then calculated values of secondary resistance agree well with test values.

B. M. Cain. If a large number of motors all made to the same specifications are tested for reactance, the tests will show variations in reactance. The variations result from many different causes, such as difference in air gap length, core length, skew, and shape and position of the end windings. Roughly speaking, I would expect in this motor a variation of 0.15 ohm in the unsaturated reactance per mil change in length of air gap in the 440-volt connection.

It is not possible to evaluate accurately all of the possible variations so as to calculate their effects on the leakage re-

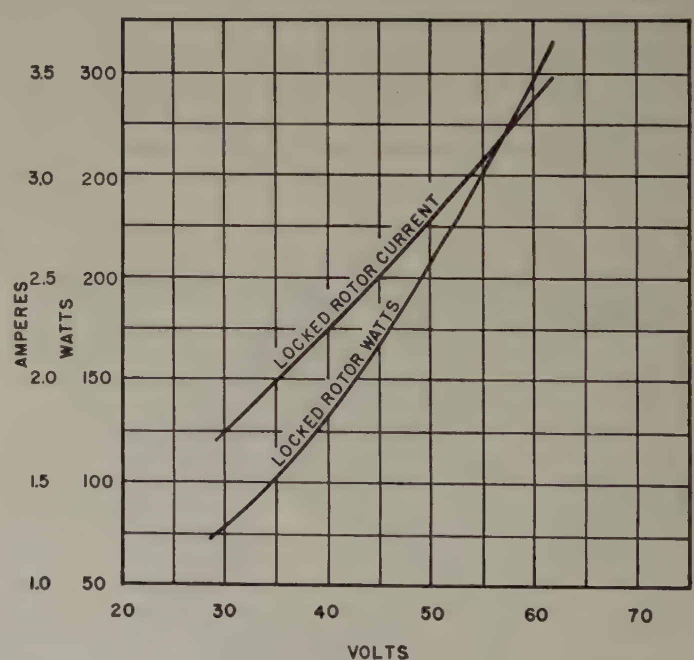

Figure 4. The 25-cycle impedance test of the 440-volt connection

Amperes, watts, and volts are average values of three tests

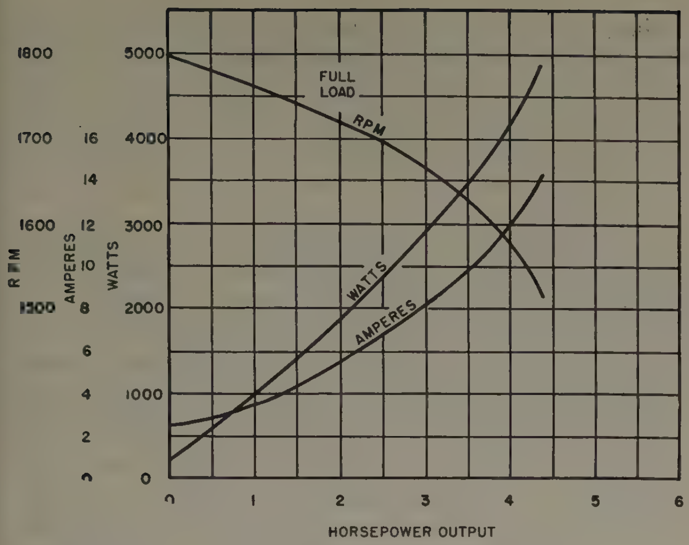

Figure 5. Load test of the 220-volt connection

Maximum torque = 17.75 pound-feet at 1,400 rpm

actance. It is far less possible to measure and evaluate these quantities on an individual sample. Consequently, the reactance calculation is not expected to predict the exact test value. Instead, it predicts the probable range to be obtained from tests on a great many samples. A particular sample may fall anywhere within the predicted range.

Observation of a large number of tests indicates that the standard deviation for leakage reactance of motors in the 1- to 15-horsepower range is about 3 per cent. The probable range of test values for a large number of tests would be plus or minus three standard deviations or say plus or minus 10 per cent. Consequently, the tested reactance of a single sample would be expected to be within plus or minus 10 per cent of the calculated value, if the calculated value is the true average.

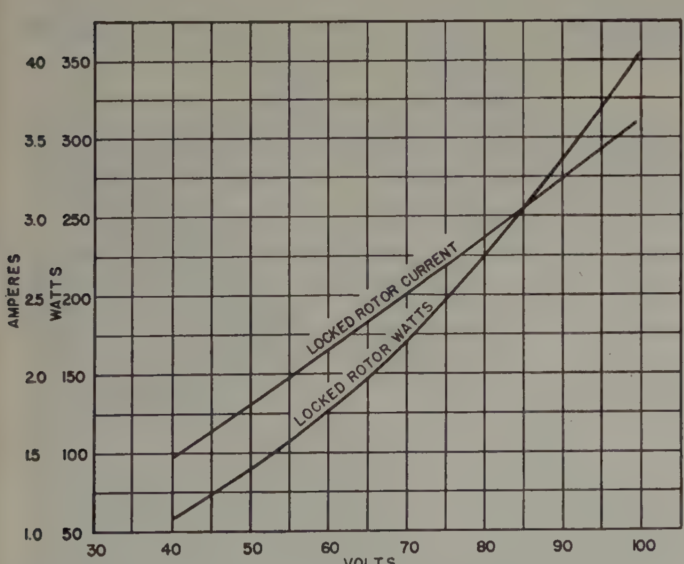

Figure 6. The 60-cycle impedance test of the 440-volt connection

Amperes and watts are average values of three tests

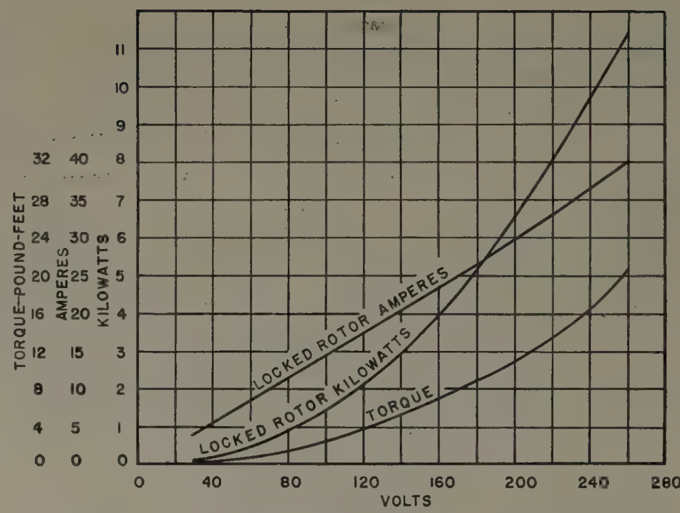

Figure 7. Locked rotor test of the 220-volt connection

W. H. Formhals. Under locked conditions at full voltage, the slot and zigzag elements of reactance are reduced by saturation from the values given in Table I to 3.8 and 4.8 ohms, respectively. Adding these to the end leakage of 4.1 ohms gives a total saturated reactance value of 12.7 ohms. This gives a locked rotor current of 16.5 amperes at full voltage on 440 volts, and a torque of 200 per cent of full load torque, or 12.1 pound-feet; which compares with 16.9 amperes and 13.6 pound-feet observed. Pull-out torque was 340 per cent of full load torque, or 20.57 pound-feet.

The full load efficiency is calculated to be 84 per cent, the power factor 0.85, and magnetizing current 1.18 amperes.

T. C. Lloyd. The detailed calculations for this motor from which the predicted value of 13.1 ohms reactance (Table I) was obtained, are given in our companion papers.[8] It is interesting to note that similar calculations, made by the methods published in five of the well-known

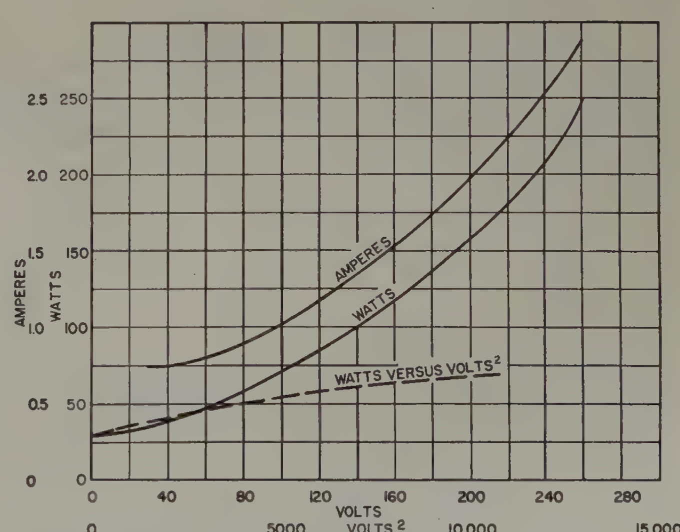

Figure 8. No load test of the 220-volt connection

books on electric machinery, give the results shown in Table IV.

Table IV. Locked Rotor Reactance Unsaturated

Ohms Per Phase Y at 440 Volts

Adams	12.0
Kuhlmann	11.7
Gray	13.6
Arnold (first method)	14.7
Arnold (second method)	14.1
Punga and Raydt	11.5

L. M. Nowacki. In calculating the reactance of this motor, I used formulas largely based in Alger's work of some 20 years ago, that are calibrated to fit induction motors in the 15-horsepower and larger size range.

P. H. Trickey. In my calculations, I used slot reactance formulas based on Adams' and Alger's paper, a zigzag reactance formula modified slightly from that of Adams, and an end leakage formula modified from that of Kilgore. I have added a reactance term equal to one-third of the belt leakage given by Adams for wound rotor motors, to cover very roughly some differential leakage not covered by the zigzag reactance. This procedure has given quite satisfactory results, although I particularly have been concerned with motors having closed slots which are not very amenable to exact calculations.

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High Capacity Experimental Circuit Breaker

In one of two tests performed at Westinghouse Electric Corporation's high power laboratory at East Pittsburgh, the equivalent of approximately five million kva at 345 kv was interrupted successfully in less than three cycles from inception of a bolted fault to extinction of the arc. Full power from two 60,000-kva generators was applied to only one pole of the circuit breaker to duplicate the heaviest current of a 3-phase fault, and voltage to ground was held at 198 kv, the equivalent of 345 kv between lines. AIEE winter meeting guests are shown here watching the tests.

A New Line of Thyratrons

A. W. COOLIDGE, JR.
ASSOCIATE AIEE

THE WIDE ambient-temperature range, small size, and quick heating of gas-filled thyratrons are important characteristics that encourage their use in many industrial applications. Experience has shown, however, that available gas-filled thyratrons have suffered from gas cleanup and short tube life when used in circuits that apply a high inverse anode voltage immediately after current conduction. When these conditions obtain, cleanup is caused by ion bombardment of the anode so severe that ions penetrate the anode surface and permanently become trapped.

The greater the rate of current decay just before the end of conduction and the rate of inverse voltage rise just after conduction, the more severe is the ion bombardment of the anode. These two rates are determined by circuit constants, and the product of these rates, measured in amperes per microsecond and volts per microsecond, is considered to be a measure of the severity of operating conditions of a particular circuit.

In circuits of the type used in electronic motor controls, the product of these two rates may become extremely high when the load current is continuous. To hold the product of the two rates to a low value, it has been necessary to connect a series-resistor-and-capacitor combination, known as a "snubber," across each thyratron from anode to cathode. The snubber lowers the rate of rise of inverse voltage. Then deionization may take place while the inverse anode voltage is low, resulting in reduced ion bombardment. During operation a continuous power loss occurs in the snubber resistor, the size of the loss depending on the amount of snubbing required.

The main object in the development of a new line of gas-filled thyratrons was to produce tubes having a high degree of freedom from gas cleanup. For a given anode voltage rating, the pressure to which the tube may be loaded increases as the electrode spacing decreases. To permit maximum loading pressure, a design was devised in which the tube elements are spaced closely by means of thin insulators.

Figure 1 shows the general construction of the 6.4-ampere tube in which the parts of the grid-anode structure are located concentrically and supported by three insulator stacks, one of which is shown in section. The filament is located in a cylindrical heat shield below the grid-anode structure. Starting with the first large cup above the cathode assembly, the elements are, shield, control grid, shield, anode, and shield. The three shields are connected together internally to the cathode. The two shields below the anode have a circular opening at their centers, the center of the control grid is perforated. The close spacing of the electrodes also limits the number of ions available for bombardment of the anode, and the thorough shielding of the anode leaves a small area exposed to ion bombardment.

The first tube to be developed was the *GL-5545* having average and peak current ratings of 6.4 and 80 amperes,

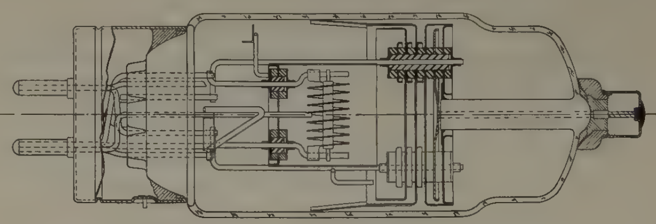


Figure 1. Cross section of the GL-5545 gas-filled thyratron

a 50-watt filament, and an anode voltage rating of 1,500 volts. The dimensions are $2^5/_8$ inches in diameter by 8 inches in length. The *GL-5545* has been life tested in typical motor controls under the conditions shown in Table 1. In each test two tubes were used in a biphase half-wave rectifier circuit. In test 1 a snubber was used while in test 2 no snubber was provided, and the inverse voltage was applied at a high rate. When the same tests were repeated on gas-filled thyratrons of older design in which the anode is unshielded and the grid-anode spacing is large, tests 1 and 2 yielded tube lives of 300 and 250 hours respectively.

The *GL-5545* ratings permit a maximum value of ten for the product of the rates of current decay in amperes per microsecond and inverse voltage rise in volts per microsecond. For most industrial circuits this means that little snubbing if any is required. It is planned that other tubes ranging in average current ratings from 1/2 through 12.5 amperes will be developed having features similar to those of the *GL-5545*.

Tests have established the value of combating gas cleanup by employing a design in which the elements are spaced closely and the anode well shielded. Excessive cleanup is eliminated by a combination of the following:

1. The tube is filled with a generous gas supply.
2. Minimum area of the anode is exposed to ion bombardment.
3. Ion population is small.

Table I. Life Test Results for the GL-5545 With Snubber (Test 1) and Without Snubber (Test 2)

Per Tube Values	Test 1	Test 2
Average current (amperes)	2.5	4.75
Peak current (amperes)	5	9.5
Peak inverse voltage (volts)	1,000	1,000
Rate of rise of inverse voltage in volts per microsecond	10	50–100
Rate of current decay in amperes per microsecond	0.15	0.15
Product of inverse voltage rise and current decay	1.5	7.5–15
Tube life hours	4,000	3,500

Digest of paper 48-171, "A New Line of Thyratrons," recommended by the AIEE committee on electronics and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

A. W. Coolidge, Jr., is with General Electric Company, Schenectady, N. Y.

Microwave Frequency Standards

B. F. HUSTEN   HAROLD LYONS
MEMBER AIEE

Initiated by a request of the joint communications board of the United States Joint Chiefs of Staff, the development of a microwave frequency standard was completed in June 1945 by the National Bureau of Standards with the assistance of the Massachusetts Institute of Technology radiation laboratory. Frequency measurements and calibrations of frequency meters or voltage sources in the microwave range now are possible as a regular calibration service.

THE National Bureau of Standards microwave frequency standard was designed to provide continuous frequency coverage from approximately 300 megacycles per second up to at least 30,000 megacycles per second. There is also provision for the generation of spot frequencies of highest precision at approximately one-per cent intervals over the same band of frequencies. The completed unit was designed to be comparatively easy to operate and maintain, to be as free as possible of all spurious frequencies, and to provide sufficient power over the entire range so it would be possible to calibrate most microwave frequency meters without resorting to external voltage sources.

The standard microwave frequencies are obtained from the National primary standard of frequency at 100 kc per second through a system of frequency multiplication, frequency conversion, and harmonic selection. The National primary standard consists of nine quartz-crystal oscillators which automatically are compared with each other and with Naval Observatory time. The absolute value of the frequency of any one of these oscillators is known at all times to within one part in 100 million.

CONTINUOUS COVERAGE SYSTEM

The block diagràm in Figure 1 shows the microwave standard set up for continuous coverage. The 100-kc output from the primary standard, after passing through a distribution amplifier, is multiplied to 7,500 kc. The frequency then is added to the output of one of two precision variable oscillators to give an output which is variable from 9.5 to 10.3 megacycles. Although, for simplicity, it is not shown in the block diagram, it is possible to add a fixed frequency to the output of either of these oscillators through the equipment used for spot frequency generation so as to obtain a frequency range from 2.0 to 3.0 megacycles, which when added to the 7.5-megacycle frequency results in an output variable from 9.5 to 10.5 megacycles. To reduce the level of undesired modulation products, particular attention was given to the design and construction of the frequency converter where the output of the variable oscillator is combined with the 7.5-megacycle frequency obtained from the primary standard.

The output of the converter is passed through four consecutive frequency triplers with outputs available in the vicinity of 30, 90, 270, and 810 megacycles. Each of these stages has a tuning range of slightly greater than 10 per cent so as only to accommodate the range of variable frequency, making it impossible to tune to any except the proper harmonic. The output from any one of these four tripler stages can be impressed across a nonlinear element such as a crystal rectifier which will generate higher-order harmonics. The frequency stability of any one of the harmonics will be directly dependent upon the output of the 10-megacycle frequency converter which, in turn, is about 75 per cent dependent upon the primary standard and only 25 per cent dependent upon the precision oscillators. These oscillators are equipped with micrometer dials which give a change in frequency of about five parts in a million per dial division. The instantaneous frequency of the oscillators can be measured to within one cycle by means of the equipment on the right of the block diagram. This equipment consists of a frequency

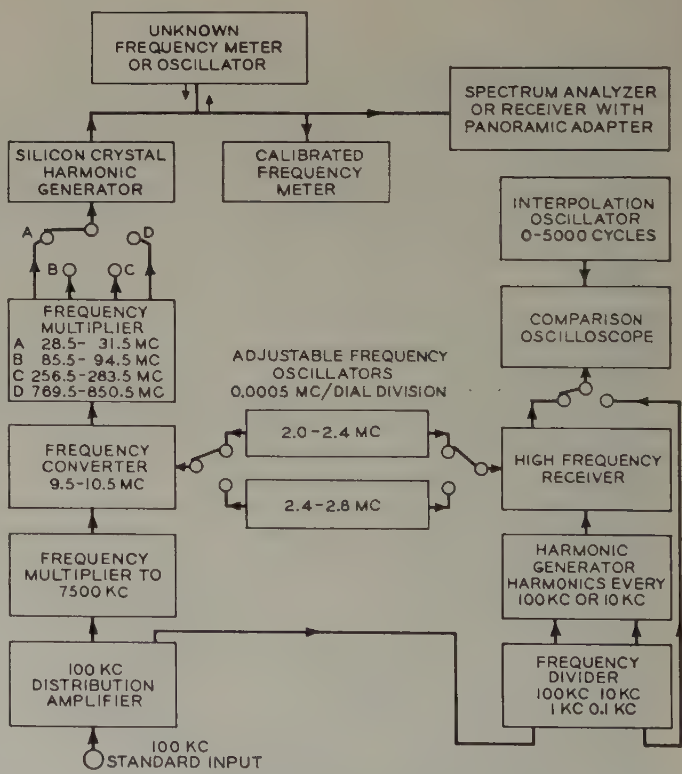


Figure 1. Microwave frequency standard continuous coverage with adjustable oscillators

MC = Megacycles

Essential substance of paper 48-49, "Microwave Frequency Measurements and Standards," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

B. F. Husten and **Harold Lyons** are both with the National Bureau of Standards, Washington, D. C.

divider, harmonic generators, a receiver, a comparison oscilloscope, and an audio-frequency interpolation oscillator.

Harmonics controlled directly by the primary standard are produced at intervals of 10 kc per second in the receiver. The unknown frequency and one of these harmonics beat together to produce a beat note which can be measured to within a cycle by means of the interpolation oscillator and the comparison oscilloscope. The interpolation oscillator, in turn, can be calibrated directly against the primary standard.

When the frequency of the variable oscillator is known to within one cycle, the 10-megacycle output and the resulting microwave harmonic are known to within one part in 10 million.

SPOT FREQUENCY SYSTEM

At times a calibration is not desired at any particular frequency but at several points within a range of frequencies. To obtain such a series of precisely known frequencies easily, the spot frequency generating equipment is used. Figure 2 shows a block diagram of the microwave standard set up for such use. One very apparent simplification is obvious from a comparison with the general coverage system as shown in Figure 1. No auxiliary frequency measuring equipment is needed as the frequency is at all times dependent directly upon the primary standard. The precision oscillators now are replaced by a system of multipliers and converters, called the decade generator, which provides an output adjustable in 100-kc steps from 2.0 megacycles to 3.0 megacycles. This is accomplished by adding to a 2.0-megacycle frequency the output of any one of a series of frequency multipliers which provide outputs every 100 kc from 100 to 1,000 kc. This frequency then is added to the 7.5-megacycle output and passed through the frequency multipliers as in the previous instance. Any one of the outputs is now adjustable over an approximately 10-per-cent range at intervals of 1 per cent. Because these frequencies are derived directly from the primary standard, they are known to within one part in 100 million.

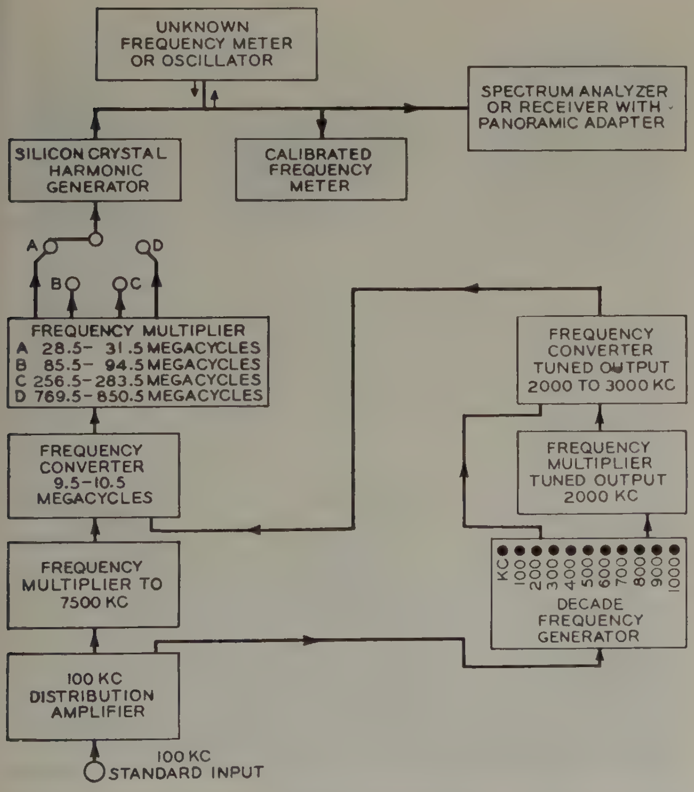


Figure 2. Microwave frequency standard spot frequency coverage

FINE TUNING SYSTEM

An additional arrangement of the equipment is possible, namely the fine tuning arrangement. This consists of a precision oscillator variable between 500 and 600 kc which can be mixed with the outputs of the decade frequency generator and multiplier to give continuous coverage from 2.0 to 3.0 megacycles. The stability of the output from the 10-megacycle converter stage with this system is 95 per cent dependent upon the primary standard and about 5 per cent dependent upon the oscillator. The advantage of this system over the previous continuous coverage system is that each dial division of the oscillator changes the frequency about one part per million as compared with the change of five parts per million of the other oscillators. The frequency of the oscillator is determined by the interpolation equipment as in the previous instance, and the accuracy of the final frequency is within one part in 10 million.

GENERATION OF HIGHER-ORDER HARMONICS

Although the output from the microwave frequency standard is tunable over a relatively narrow frequency range, continuous frequency coverage can be obtained through the overlapping of harmonics. With the 10-per-cent bandwidth being used, harmonics of the output above the 10th overlap and provide continuous coverage. The output of any one stage must be used up to the 30th harmonic before the harmonics of the succeeding stage begin overlapping. The power level of the 30th harmonic of any one of the stages is sufficient for frequency calibration purposes.

To generate these high-order harmonics the output from any one of the four frequency multiplier stages is impressed across a crystal diode mounted in a coaxial line or a section of wave guide, whichever the case may be.

The crystal is mounted in the wave guide with appropriate tuners so it not only generates the harmonics, but also serves as an antenna for the efficient radiation of the microwave energy down the guide.

The power which these crystals can handle without overloading or burning out is limited. Some of the crystals designed to operate in the vicinity of 1,000 megacycles can handle several watts of power without being damaged, but most of the higher frequency crystals can handle only a few tenths of a watt. Strength of some of the harmonics is as low as 0.05 microwatt, but because the sensitivity of the receiver is about 10^{-6} microwatt, there is sufficient power to perform most calibrations.

When a wave guide is used to propagate these higher-order harmonics, no difficulties ever are encountered with lower harmonics or with the fundamental itself because the wave-guide transmission line is an excellent high-pass

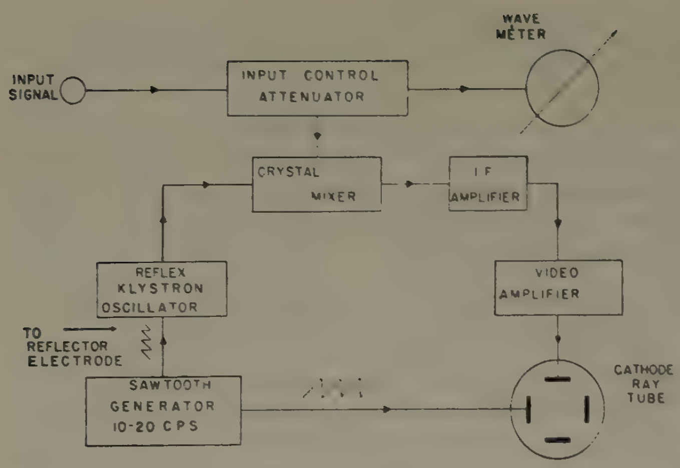


Figure 3. Block diagram of spectrum analyzer

filter, passing only those frequencies which are above the cut-off frequency. When coaxial line is used for the transmission of the energy, it is sometimes necessary to employ tuned stubs or filters in the line to eliminate the stronger lower-order harmonics.

RECEIVING EQUIPMENT

A superheterodyne receiver is used with a panoramic adapter for the frequencies below 2,700 megacycles.

The spectrum analyzer which is essentially a superheterodyne receiver with a frequency-modulated local oscillator is used for the higher frequencies. A block diagram of a typical spectrum analyzer receiver is shown in Figure 3. The local oscillator, a klystron tube, is frequency-modulated by means of a saw-tooth wave. This same saw-tooth wave is impressed upon the horizontal plates of a cathode-ray tube. The video output of the receiver is impressed on the vertical plates of this tube. Whenever the difference between the input frequency and the frequency of the local oscillator is equal to the intermediate frequency of the receiver, a pip will appear on the screen of the cathode-ray tube. The height of this pip will be a function of the input power and the position on the screen will be a function of the input frequency and the center frequency of the local oscillator. There will be two such pips for each frequency although they may not be on the screen simultaneously. These pips correspond to instantaneous local oscillator frequencies above and below the input frequency. When the spectrum analyzer is used to compare two frequencies, it is possible for the two to appear to coincide when they are separated by twice the intermediate frequency. When the two frequencies are in proper coincidence the two pips above the local oscillator frequency will coincide as will the two below the local oscillator.

MEASUREMENT OF MICROWAVE FREQUENCIES

To expedite the setting of the microwave frequency standard, tables of the frequencies of the various harmonics versus the variable frequency input into the 10-megacycle converter have been prepared for every 100-kc step from 2.0 to 3.0 megacycles. The frequency to be measured is tuned in on the spectrum analyzer and an approximate value of the frequency is obtained from a calibrated frequency meter. The frequency standard then is set up for the proper frequency by reference to the tables. A pair of pips should appear on the screen of the receiver and by adjusting the power level of the standard or of the generator being measured they can be made equal in amplitude. At this point a check should be made to insure that the two frequencies are approximately equal and are not separated by twice the intermediate frequency. By bringing the frequencies into coincidence and increasing the dispersion it is possible to observe the beat notes on the screen. These beat notes appear as a filling-in of the response curve on the screen. It is possible with this method to determine the frequency of an oscillator to within one part in one million, which is considerably better than the stability of most microwave oscillators. If greater precision is warranted, it is possible to dispense entirely with the spectrum analyzer method and to measure the audio beat note of the two frequencies by any one of several methods.

MICROWAVE FREQUENCY METERS

Microwave frequency meters in common use are of three types: coaxial-line, cylindrical-cavity, and transition, which is a combination of the other two. The meters also may be called, resonant cavities, or cavities. These meters may be of either the transmission type or the reaction type. The reaction-type meter is coupled into the main transmission line through a T section or through an iris in the side of the wave guide. The coupling is adjusted so the meter will present a high impedance in series with the wave guide when it is tuned to resonance, thereby

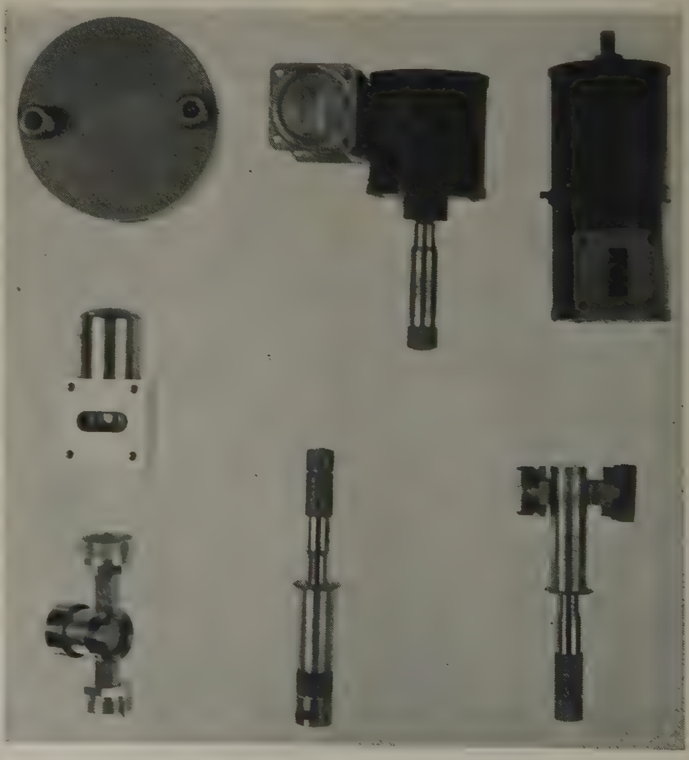


Figure 4. Microwave frequency meters

decreasing the power transfer of the guide. The meter is adjusted to resonance by tuning for minimum output.

The transmission-type meter is inserted directly into the line and the energy must pass through the meter. Resonance in this meter is indicated by maximum power transfer. In Figure 4 are shown some typical microwave resonant-cavity frequency meters.

ACCURACY OF CALIBRATION

Although the frequency from the microwave frequency standard is known to at least one part in 10 million, it is practically impossible to certify a frequency meter to this accuracy. Many factors enter into the exact determination and certification of the resonance frequency which limit the accuracy of the usual meter to about one part in 100 thousand or less.

Mechanical inaccuracies such as dial backlash, loose or faulty mode dampers, creepage of the metals or dielectrics, and lack of ruggedness are obvious limitations to the accuracy but are not the only factors which must be considered. When a precise determination of the resonance frequency is desired, such variables as temperature, humidity, and pressure may have to be considered. In addition to these factors the amount of external reactance which is coupled into the frequency meter also will affect the resonance frequency and must be taken into account or made negligible during the calibration. Finally, the sensitivity of the resonance-indicating device and the finite Q of the meter itself limit the accuracy to which resonance can be determined. Steps may be taken to reduce these limiting factors.

FUTURE DEVELOPMENTS

It is becoming more and more urgent to extend the range of the bureau's microwave frequency standard above 30,000 megacycles. This problem is being attacked by development of a lighthouse-tube frequency multiplier circuit which will provide, through the preceding multiplier chain, crystal-controlled output in the 2,400-megacycle range. By development of suitable crystal rectifier mounts, harmonic generation at a useful power level should be possible to 75,000 megacycles or above. It is also possible to use klystron frequency-multiplier tubes to obtain crystal-controlled power at 10,000 megacycles at a level of approximately one milliwatt. By harmonic generation it then should be possible to obtain useful outputs to 100,000 megacycles and above. At these extreme high frequencies it probably will be desirable to introduce new frequency measuring instruments along the lines of optical equipment. In this connection, microwave interferometer and echelon gratings have been built and have become practical.

At the present time, it is hoped that microwave frequency standards at institutions other than the National Bureau of Standards can be standardized through utilization of the standard frequency emissions from station *WWV*. This is particularly easy if the microwave frequency standard is of a type similar to that used at the National Bureau of Standards, as it only will be necessary to adjust the quartz crystal oscillator or other oscillator, serving as the starting point of the frequency multiplying chain, to the frequency of *WWV* by means of the proper receiver and intercomparison circuits. In the future, if suitable absorption lines can be found for use as frequency standards, it may be possible to calibrate the various types of microwave frequency standards, wherever located, through the use of spectroscopic frequency standards. At the present time frequency measurements and calibrations of frequency meters or voltage sources can be obtained from the National Bureau of Standards as a calibration service similar to the standards services rendered by the bureau in other fields of measurement.

The Electrogyro

That a large amount of energy can be stored in a heavy high-speed flywheel is well known. A recent development in Switzerland, described in the March 1948 issue of *Power Generation*, uses this stored energy as a source of power for considerable periods of time.

The device is a vehicle which is operated from the energy stored in a rotating flywheel, and is known as the "electrogyro." This electrogyro has a flywheel of high-tensile chrome-nickel steel which is supported by liberally dimensioned ball races in a closed hydrogen-filled container. The squirrel-cage rotor of a 3-phase change-pole induction motor is built on to the flywheel, which, when connected to a low-voltage 3-phase supply, accelerates the flywheel to approximately 3,000 rpm. Under normal conditions this charging process takes place in about one minute. Because the motor housing is filled with hydrogen, the cooling is excellent and the windage losses are held to a minimum. The running down time of such a gyro-drive unit when the vehicle is stationary is about 10 to 15 hours.

When the vehicle is traveling the motor operates as an asynchronous generator and delivers 3-phase current to the traction motors. These are constructed as squirrel-cage change-pole motors and permit a speed variation of one to five practically without additional losses in the experimental model.

The experimental model was built by Ateliers de Construction Oerlikon, Zurich-Oerlikon, and it is reported as operating satisfactorily. With a trailer coach the vehicle can travel a distance of six to nine miles between recharging, which is adequate for the distance between stations usual on most transport systems.

This type of vehicle is useful chiefly for services on routes without excessive gradients, and with regular stops not too far apart. It can be used on main line railways, streetcar lines, suburban railways, or motor bus routes. An important use is for factory and shunting locomotives.

In the model built the circuit was so arranged as to permit direct operation, without any modification of the equipment, from overhead trolley sections fed with 50-cycle single-phase current. This allows operation at will directly from the overhead trolley or by the energy reserve stored in the electrogyro on sections without the overhead trolley.

Electrical Properties of Ceramics

E. W. LINDSAY
ASSOCIATE AIEE

L. J. BERBERICH
FELLOW AIEE

HIGH-TENSION procelain long has been and still is one of the most important ceramics used in the electrical industry. For high-temperature and high-frequency applications, however, it has some deficiencies which are not present to the same degree in the newer oxide procelains, among which are zircon and alumina procelains. Data on dielectric strength, resistivity, and power factor were obtained over a range of temperature for these two oxide porcelains as well as for high tension procelain. The temperature range covered extends up to 1,000 degrees centigrade.

It was found that when the logarithm of the dielectric strength, resistivity, or power factor is plotted against the reciprocal of the absolute temperature, two straight lines result. The intersection of these straight lines define a transition temperature. The transition temperatures for the dielectric strength data coincide approximately with the transition temperatures determined by the resistivity and the power factor data. This was found to be true not only for the three porcelain samples investigated, but also for mica and fused silica, data for which were obtained from the literature. The data on dielectric strength and resistivity for zircon procelain given in Figure 1 are typical of those for the other materials.

As far as dielectric strength is concerned, the transition temperature separates two regions of breakdown, which usually are referred to as the low temperature or disruptive region and the high temperature or thermal region of breakdown. In general, the breakdown strength decreases rapidly in the thermal region and, therefore, the transition temperature also should be the approximate temperature above which it is unwise to use the material, particularly at high-voltage stresses. Transition temperatures for the materials considered in this investigation are listed in Table I.

Table I. Transition Temperatures for Various Materials

Material	Transition Temp C
High-tension porcelain	100
Zircon porcelain	220
Alumina porcelain	250
Fused silica	250
Muscovite mica	380

The coincidence of transition temperatures between the two regions of breakdown and the two regions of conductivity leads one to suspect that both transitions might be ascribed to the same cause. Attempts were made to correlate the transitions as determined by dielectric strength or resistivity with crystalline and second order transitions, but no such correlation was found. The transition temperatures appear to be too low for the onset of bi-ionic conduction which was observed at higher temperatures in sodium chloride by Phipps and Leslie. All that can be said at this time is the transition temperatures appear to separate a region where the current flow is dominated by dielectric absorption from that where the current flow is largely the result of electrolytic conduction.

The experimental data on dielectric strength are in qualitative agreement with recent electrical breakdown theories proposed by von Hippel and Frohlich. Frohlich's critical temperatures, which separate the low and high temperature regions of electric breakdown, appear to be identical with the transition temperatures determined by the resistivity and the dielectric strength data of this investigation. Even though no quantitative agreement between theory and the apparent breakdown strengths of this investigation are expected, some refinement of the theory appears to be necessary to account for the effects of ionic conduction before actual breakdown takes place.

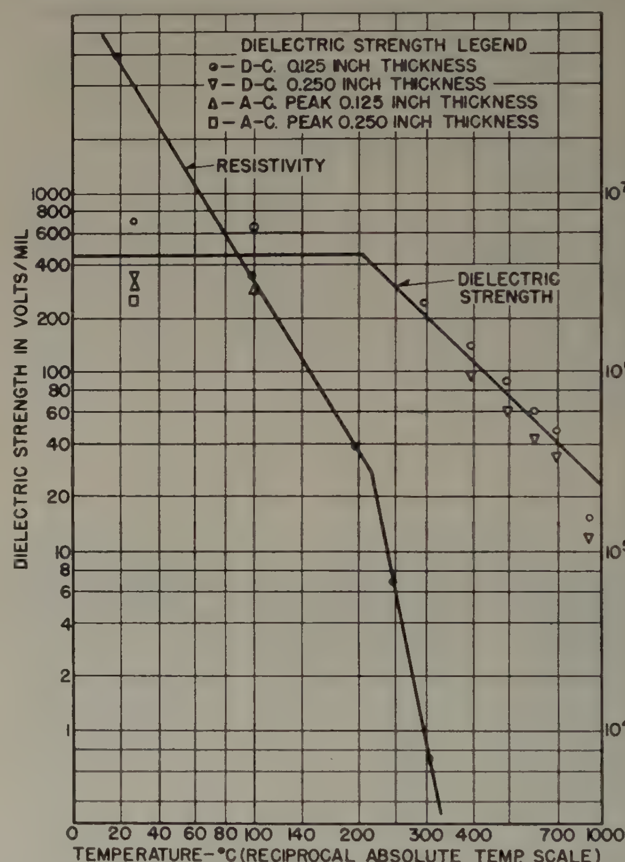


Figure 1. Variation of dielectric strength and resistivity of zircon porcelain with temperature

Digest of paper 48-175, "Electrical Properties of Ceramics as Influenced by Temperature," recommended by the AIEE switchgear and transmission and distribution committees, and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

E. W. Lindsay is research engineer in the insulation department, and **L. J. Berberich** is manager of the physical section in the insulation department; both of Westinghouse Research Laboratories, East Pittsburgh, Pa.

X-Ray Thickness Gauge for Hot Strip Rolling Mills

C. W. CLAPP R. V. POHL
ASSOCIATE AIEE

The application of X rays to the gauging of hot strip steel has been accomplished using one X-ray tube and two photoelectric tube detectors. The gauge also has other promising uses.

THE equipment described in this article was built to fill a long-felt need in hot-strip steel rolling mill practice. Heretofore, all gauging of the strip thickness, of necessity, has been delayed until the strip has cooled to a temperature where measurement by a hand-held micrometer is possible. In this length of time a modern high-speed mill may roll six or more tons of steel. Any error in mill setting resulting in an off-gauge strip is therefore very costly because of the large amount of off-gauge material produced before the error can be corrected. The need for equipment to gauge continuously the thickness of the strip as it issues from the finishing stand has been obvious for some time.

By ordinary gauging standards, the conditions under which the thickness measurement must be made are somewhat unusual. In a typical steel mill, the strip may be traveling at speeds of 2,000 feet per minute or more out of the finishing stand. As it leaves the rolls it may vibrate vertically through an amplitude of several inches and to prevent the possibility of jams or "cobbles," the clear opening through the gauge should be at least 18 inches high. The temperature of the strip is ordinarily between 1,500 and 1,750 degrees Fahrenheit. Cooling water sprays deluge the strip and any near by equipment.

THEORY

When a beam of X rays strikes a sheet of some absorbing substance such as steel, a part of the beam is transmitted through the sheet unchanged while the remainder either is absorbed within the sheet or is reradiated as scattered X rays.

Considering such qualities as sensitivity, speed of response, spectral response, long life, and convenient operation, a very satisfactory detector can be obtained by the use of a phosphorescent screen directly in front of a sensitive photoelectric tube. Such a detector was used to obtain the data for Figure 1 which shows the intensity of the X-ray beam transmitted through different thicknesses of a standard low-carbon steel for several values of voltage V applied to the X-ray tube. In this instance, the tube was operated directly from a 60-cycle high-voltage transformer and V represents the peak value of the voltage across the tube during the half-cycle when the target is positive with respect to its cathode.

The curves of Figure 1 are basic to the design of a thickness gauge for the material in question. They show for example that for a particular steel thickness and tube voltage represented by the point A, a 10-per-cent decrease in tube voltage has the same effect on the detector as a 27-per-cent increase in steel thickness. Effective means therefore must be found to stabilize or compensate for changes in tube voltage to secure a reasonable accuracy in gauge reading. The curves also show that for a given small change in steel thickness the corresponding change in detector reading is not constant but decreases in general as the thickness of steel is increased. This behavior complicates the design of a gauge having a linear scale over a wide range of thicknesses.

DESCRIPTION

As shown in Figure 2, ports are provided in the enclosure for the X-ray tube to select two beams from the total radiation to be designated as the reference beam and the measuring beam, respectively.

The reference beam first passes through a long wedge of absorbing material (standard wedge) then falls on radiation detector *1*. The output of the detector is a direct voltage whose magnitude and polarity are a measure of the difference between the intensity in the reference beam and a standard reference intensity established within the detector for comparison purposes. The output voltage of this detector is used to control an electronic voltage regulator in the primary circuit of the high-voltage transformer supplying the X-ray tube. By thus automatically controlling the voltage on the X-ray tube, the intensity in the reference beam is maintained at a level such that, after partial absorption in the standard wedge, it will have the value determined by the reference standard in detector *1*.

The measuring beam first passes through a thin wedge of absorbing material (measuring wedge) then through the thickness of steel to be measured and falls on the radiation detector *2*. Again the output of this detector is a direct voltage measuring the difference between the intensity of the beam striking the detector and a standard reference intensity established within the detector for comparison purposes. The output voltage of this detector, in turn, is used to control a motor geared to the measuring wedge. When the intensity in the measuring beam is different from the reference intensity, the motor shifts the wedge in a direction to increase or decrease the absorption in the

Essential substances of paper 48-100, "An X-Ray Thickness Gauge for Hot-Strip Rolling Mills," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

C. W. Clapp and R. V. Pohl are both with the high frequency division of the general engineering and consulting laboratory of the General Electric Company, Schenectady, N. Y.

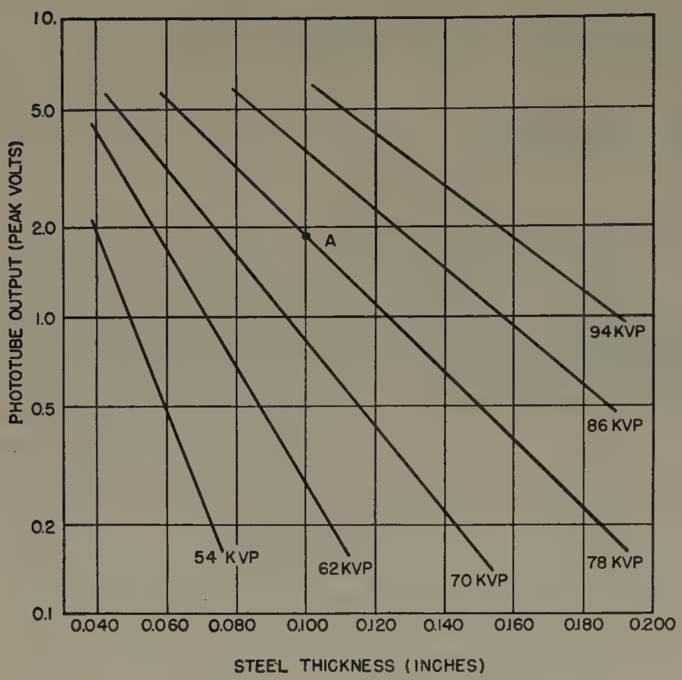


Figure 1. Absorption of X rays in steel with tube operated at various alternating potentials

beam as required to maintain the intensity at the value determined by the reference standard in detector *2*.

In operation, the reference standards in the two detectors are adjusted so that the measuring wedge comes to rest when the total absorption in the path of the reference beam equals the total absorption in the path of the measuring beam. By making both wedges of steel, the thickness of the unknown steel sample can be obtained simply as the difference between the effective thickness of the two wedges. To provide a simple means of reading the gauge, the positions of the two wedges are transmitted through separate Selsyn systems to two scale pointers on a remote indicator panel. One of these pointers, connected to the standard wedge, indicates the nominal steel thickness to which the gauge is set. The second pointer, connected to the measuring wedge, indicates on a zero-center scale the deviation in sample thickness from the nominal gauge size.

To set the gauge to a different value of nominal steel thickness, the standard wedge must be moved to present a different thickness to the reference beam. This is done by means of a small reversible motor controlled by push buttons on the remote indicator panel. The same motor also is linked through a cam mechanism to the arm of a variable-ratio autotransformer connected in the primary of the X-ray high-voltage transformer. As the standard wedge thickness is altered, the voltage on the X-ray tube thus is adjusted automatically to the approximate value needed to maintain the required intensity in the reference beam striking detector *1*. The range over which the electronic voltage regulator must supply correction thus is reduced greatly.

RADIATION DETECTOR

The circuit of the radiation detector is shown in Figure 3. This employs a *931A* multiplier-type photoelectric tube with a thin layer of silver-activated zinc sulphide phosphor cemented to the outside of the tube envelope opposite the cathode surface. When excited by X rays, this phosphor emits light having most of its energy at a wave length of 4,350 angstroms. Since the *931A* has its peak response at 4,200 angstroms, this makes a reasonably sensitive combination. Photoelectric tubes of this type vary widely in sensitivity but average tubes so coated have been found which, when placed in a beam of 50 milliroentgens per hour, gave a signal 30 decibels above tube noise. The sensitivity of the multiplier-type photoelectric tube varies rapidly with changes in electrode voltage, and is subject to fatigue effects. These disadvantages have been overcome by requiring only that the photoelectric tube compare the relative strengths of two light signals and indicate which of the two has the greater intensity. The first of these signals results from the excitation of the phosphor by the X-ray beam and consists of half-wave pulses occurring at line frequency. The second light signal is obtained from a glow discharge lamp of a type recently developed for light-modulator service. This lamp is connected to the 60-cycle line through a ballast resistor, and is shunted by a diode rectifier to ensure its excitation only on the alternate half-cycles of line voltage when no X rays are being emitted. The light from this lamp, after being suitably attenuated through filters, is directed through the phosphor onto the cathode of the photoelectric tube.

To compare the two peak values, the signal from the photoelectric tube first is amplified through a linear amplifier, then applied to the grids of the phase-sensitive triode detectors. In this circuit, the plates of the two detector tubes are supplied with voltages of equal amplitude but opposite phase through a center-tapped transformer connected to the 60-cycle

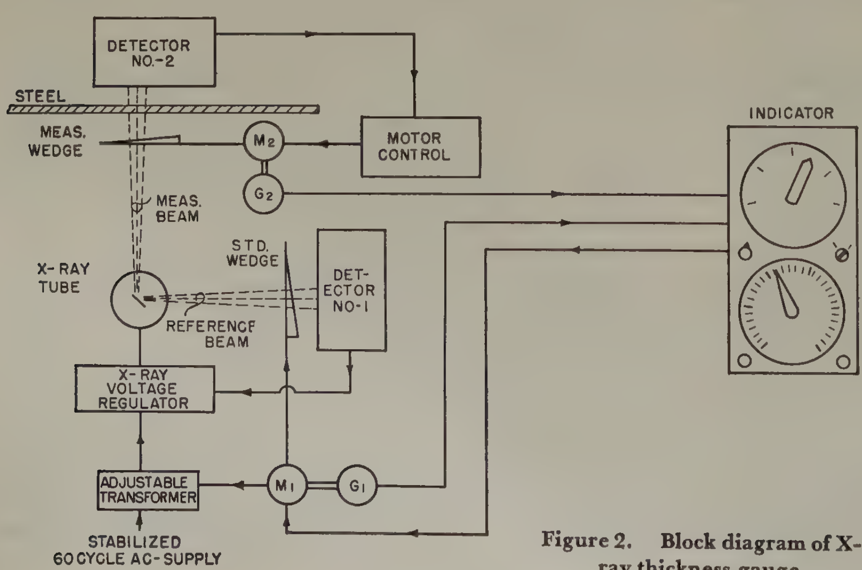
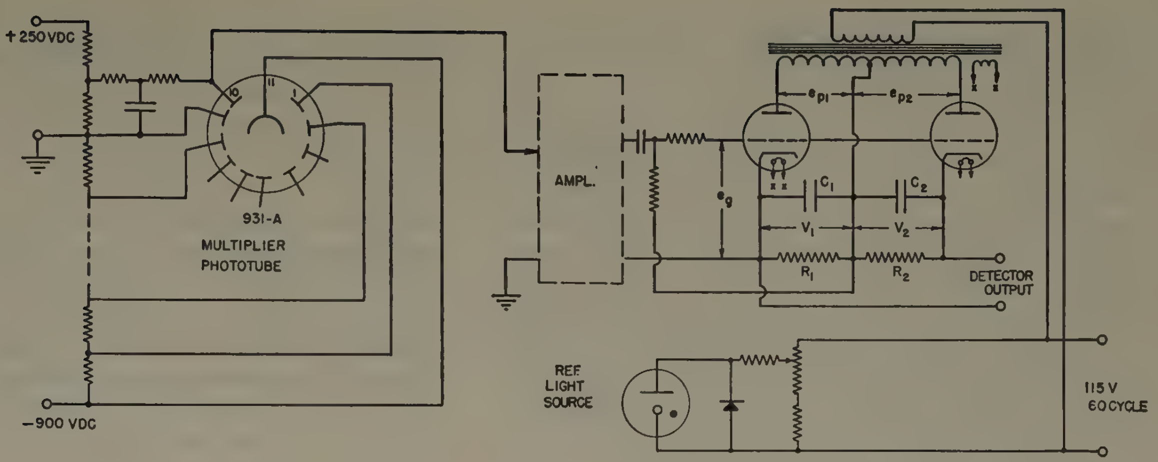


Figure 2. Block diagram of X-ray thickness gauge

Figure 3. Circuit diagram of radiation detector



line. The cathode load resistors R_1 and R_2 are made very large compared with the reciprocal of the mutual conductance for the triodes and the capacitors C_1, C_2 are selected so that the time constants R_1 C_1 and R_2 C_2 are long compared with the period of the signal wave. Under these conditions the capacitors C_1 and C_2 charge up to steady voltages V_1 and V_2 sufficient to maintain their respective tubes close to or beyond plate current cutoff at all times. Because the plate voltage on one of the triodes, say e_{p1}, has its maximum value when the signal from the X-ray beam is a maximum, and the plate voltage on the second tube (e_{p2}) reaches its maximum in phase with the signal from the reference light source, V_1 and V_2 are linear functions of the peak values of the X-ray signal and the reference light signal respectively. The output of the detector, consisting of the voltage $(V_2 - V_1)$, is therefore zero when the two signals have equal peak values and at other times has a value proportional to the difference between the two signals.

ELECTRONIC REGULATOR

The circuit diagram for the electronic regulator used to control the accelerating voltage on the X-ray tube is shown in Figure 4. This regulator operates by varying a resistance element connected in series with the primary of the high-voltage X-ray transformer. The resistance element consists of the plate resistance of four *807* tubes connected in parallel. The transformer T_2 serves to provide a proper impedance match between the plate circuits of the tubes and the power line circuit into which they operate. To utilize the *807* tubes efficiently, their screens are maintained at a steady direct potential. The grid bias on the tubes is controlled by the output of radiation detector *1*, amplified through one stage of d-c amplification. When connected as shown the tubes carry current only on one half-cycle of the line voltage, this of course being the half-cycle during which the X-ray beam is emitted. The resistor serves a dual purpose; it limits the voltage appearing across the tubes on the negative half-cycles of voltage and during the warm-up period of the tubes, and it increases the regulating range of the circuit.

OPERATING PERFORMANCE

The X-ray tube and associated high-voltage and filament supply are housed in a single unit and are contained in a lead-lined oil bath, with forced oil circulation to the anode of the tube and separate water cooling of the oil. The tube used has a tungsten target and is rated at 100-kv peak. Also contained in this unit are the two steel wedges, with their associated motor drives and connected Selsyn transmitters, and the photoelectric tube and reference light source for detector *1*.

The photoelectric tube and reference lamp for detector *2* are mounted in a separate water-cooled steel housing. At installation, this unit is mounted about 24 inches above the lower unit and is centered in the measuring beam which is directly vertically upward from the lower unit.

A cabinet houses the remainder of the electronic detection and control equipment as well as the power supplies for all circuits.

A remote indicator shows the nominal gauge size in thousandths of an inch and the deviation of the steel thickness in thousandths of an inch from the nominal size. Means are provided at the indicator station to correct the

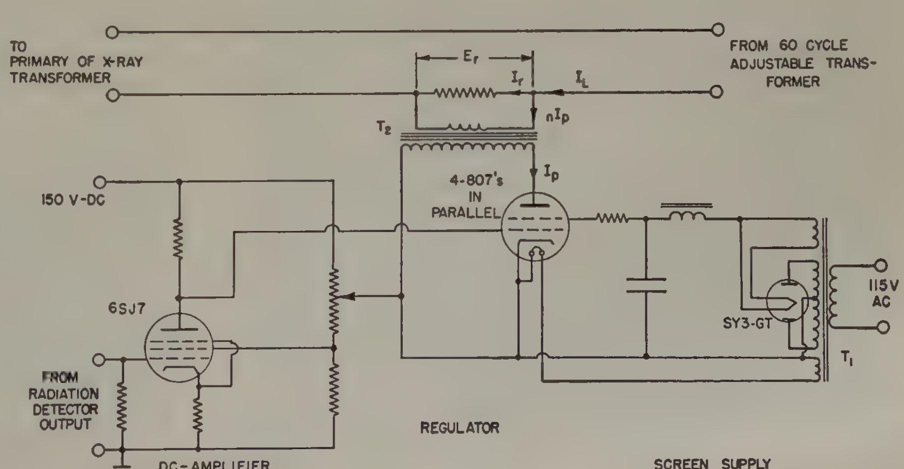


Figure 4. Circuit of electronic voltage regulator

calibration of the gauge when necessary and to select any nominal gauge size within its range.

There are certain points that should be considered in using a gauge of this type which are related to the operating conditions. Among these are the effect of impurities or changes in composition of the steel, the additional absorption of the layer of cooling water retained on the steel strip, and the contraction of the steel in cooling down to room temperature.

Fortunately, most of the alloying elements commonly used in making steel have an X-ray absorption coefficient less than or only slightly greater than that of iron. Tungsten and molybdenum are the principal exceptions to this statement, but are not commonly used in sheet steels. Stainless steel of the common 18–8 composition has an absorption coefficient within one per cent of that of iron at room temperatures and this difference readily can be taken care of by a zero adjustment during calibration. For common grades of silicon steel the correction may amount to seven per cent. The gauge dial of a gauge used for measuring several alloys has several concentric scales.

Puddles of cooling water an eighth of an inch thick frequently may be found on the strip at the measuring point. Such a layer can cause an error on order of two per cent. Where this is objectionable, the water can be removed from the measuring point by a strong air blast.

While the steel is being gauged, its temperature is in the neighborhood of 1,600 degrees Fahrenheit. As compared with the same steel at room temperature, the hot strip presents fewer iron atoms in a given cross-section of the X-ray beam and hence gives a lower reading of thickness. The correction for temperature depends only on the expansion coefficient of the steel, and for ordinary carbon steels amounts to 1.6 per cent per 1,000 degrees Fahrenheit. As the rolling temperature usually is known to within plus or minus 200 degrees, it is a simple matter to graduate the scales to correct for this error.

SAFETY CONSIDERATIONS

In a device of this type intended for use by nontechnical personnel, the question of safety must be given full consideration. The approach to this problem has been threefold. First, the unit containing the X-ray tube has been built to conform to the requirements for a Class I or fully protective housing as defined in the proposed American Standards Association Safety Code for the Industrial Use of X-Rays (*Z54.1*). This means that, except for measuring beam itself, the radiation from this unit is everywhere below the level at which it could cause harm to personnel. Second, by using sensitive detection means, the X-ray intensity needed in the measuring beam has been kept as low as possible. While a measurement is being made, the beam intensity at the upper photoelectric tube unit is approximately 50 milliroentgens per hour. Scattered radiation from the beam is below tolerance level of 12.5 milliroentgens per hour at all points more than 2 feet away from the direct beam under all conditions of use. Third, warning lights and barrier gates interlocked with the X-ray tube voltage supply have been provided at all points of access to the gauging area to prevent personnel from entering this area while the beam is on. As an additional precaution and check, it has been recommended that operating personnel carry monitor pencils until the safety of their work habits amply has been demonstrated.

OTHER APPLICATIONS

The gauge described in this article was designed to fill a specific need—that of measuring the thickness of hot-rolled steel strip. The method employed however is adaptable to many other gauging problems where a noncontacting gauge is desired. One such application is the gauging of cold-rolled steel strip where, because of the speed of the strip, the accuracy of contacting methods of gauging is reduced. The method also can be used with metals other than steel, and with various nonmetals. In all these applications, however, we must consider whether there is present in the material, in any appreciable quantity, an element whose absorption coefficient is greater than that of the element used as the basis of gauging. If such is the case, the thickness reading obtained on the gauge will depend on the relative amounts of the two elements present in the material.

A Magnetic Fluid Clutch

A new type of electromagnetic clutch has been developed at the National Bureau of Standards by Jacob Rabinow, chief of the ordinance mechanics section. He has found that frictional forces between solid surfaces and certain types of fluid media can be controlled by magnetic fields.

The magnetic fluid clutch operates on the following principle. When the space between two parallel magnetic surfaces is filled with finely divided magnetic particles, and a magnetic field is established between the two plates, the particles bind the plates together against movement parallel to their surfaces. The particles may be finely divided iron which for most applications is mixed with a liquid such as oil to prevent packing and to afford smoother operation of the clutch. When a portion of this mixture is acted upon by a magnetic field, the iron particles are mutually attracted, they bind together in the field, and the mixture seemingly "solidifies." Because an electric current can produce a magnetic field, a simple means for controlling the binding force over a wide range is available.

Preliminary tests indicate that the clutch is easy to control and requires very small amounts of electric power. The control is very smooth from the minimum, which is determined by the viscous drag of the oil, to the maximum, which is controlled by the magnetic saturation of the iron. In most electromagnetic clutches torque is proportional to the square of the current. Torque in the new clutch is proportional to the control current over a wide range of torque values. This makes the clutch particularly suitable to servomechanism applications where linearity and good control down to zero current are of primary importance.

A New Reactance Distance Relay

C. G. DEWEY
MEMBER AIEE

J. R. McGLYNN
APPLICATION PENDING

THE HIGH LEVEL of industrial and commercial activity has created a demand for electric power greater today than at the peak of wartime production. Installation of additional generating capacity and new transmission lines has been unable to keep up with this growth in power demand. This has led to transfer of additional power over existing lines, thus making dependable line relaying more vital than ever.

This transfer of additional power over existing lines has caused a corresponding increase in the number and severity of power swings, particularly on longer lines. To cope with this problem greater phase angle discrimination was required in a distance relay. Distance relays with a "mho" characteristic, which is the ability to measure a constant component of admittance for providing discrimination, in which phase angle discrimination is inherent have been used for more than two years for protecting long or heavily loaded lines because they are less liable to tripping on power swings than the conventional reactance or impedance relays.

For short lines a reactance distance relay has been used because its accuracy is not impaired by arc resistance. As the ohm unit of this relay is by nature nondirectional and will operate on load current if the reactive component of the load impedance is below its ohmic setting, a directional unit provided with voltage restraint has been used in the relay to distinguish between load and fault conditions.

Until recent years, this simple directional unit has been adequate as a fault detector in the reactance relay. However, the greater amounts of power now being transferred have enhanced the danger of tripping on power swings even on short lines, particularly if the short line embraces the electrical center of the system. For this reason a new reactance distance relay has been developed in which the present directional unit has been replaced by a mho starting unit. This new mho unit energized by the phase-to-phase voltage and the two adjacent phase currents is less likely to operate on power swings because, unlike the voltage restraint directional unit, it has the same characteristics on either balanced or unbalanced conditions.

In developing this new distance relay, it seemed logical to follow the pattern of the mho relay as applied to long lines, that is, the combination of three single-phase distance relays and a separate timing relay per 3-phase terminal.

The timing relay is simple in construction, accurate, and consistent. The time of operation is regulated by a magnetic damping element shown in Figure 1. The operating magnet, shown in Figure 2, is a curved solenoid which produces a rotary motion without the use of gears.

The new reactance relay terminal has the inherent high speed and accurate distance measurement of the present relay. In addition it has the following advantages:

1. The mho starting unit reach is the same for all faults involving more than one phase.

2. The new timing relay provides more accurate and consistent timing. It has a radically new operating magnet and employs a powerful magnetic damping element both of which reduce the gearing to one set of gears.

3. Only a single-phase supply is required for making tests.

Digest of paper 48-178, "A New Reactance Distance Relay," recommended by the AIEE relay committee and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

C. G. Dewey and J. R. McGlynn are both with the General Electric Company, Philadelphia, Pa.

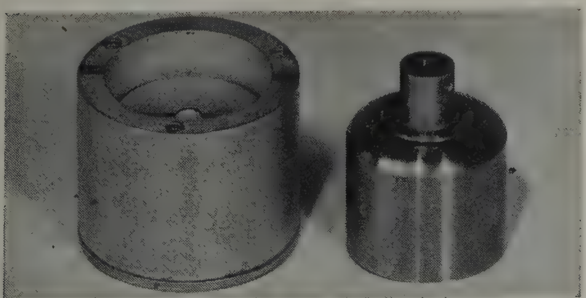


Figure 1. The magnetic damping element of the new relay

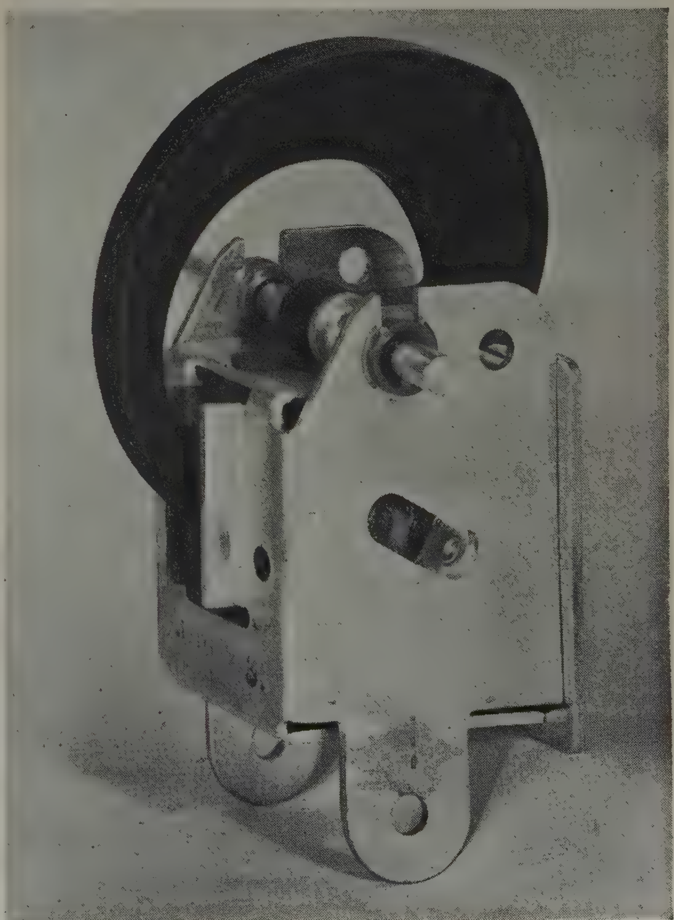
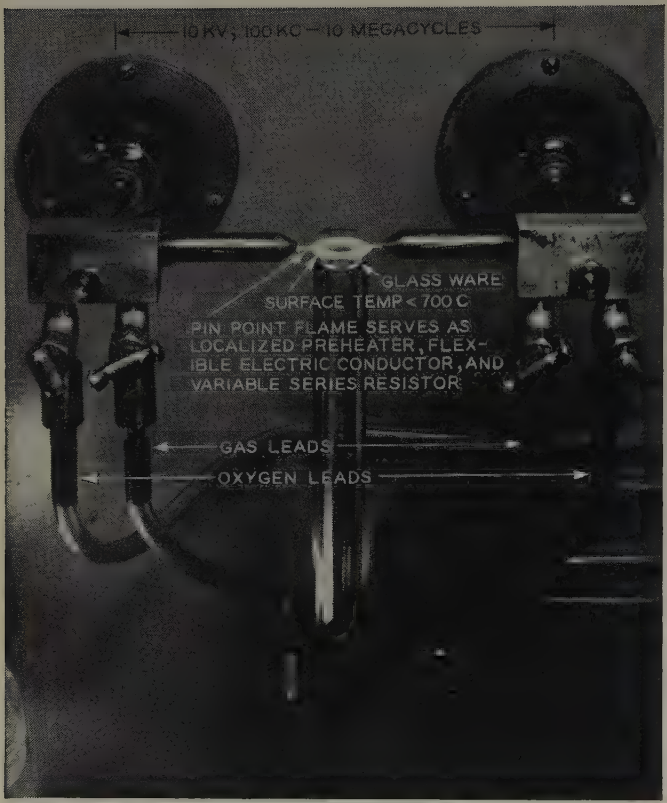


Figure 2. The rotonoid operating magnet of the new timing relay

Electric Welding of Glass

E. M. GUYER
ASSOCIATE AIEE



(Above) Two small gas–oxygen pin-point fires preheat localized areas of the rotating glass bowl to be welded. At this temperature the glass becomes an electric conductor. High-frequency current then is passed through the flames into the glass and the operation is completed by electric melting.

ALTHOUGH glass can be ground, sawed, and drilled in the solid state, its hardness is such that many operations are performed most easily on glass which has been reheated to a plastic state. From early antiquity, fire and heat have been used for sealing, moulding, and joining glass parts together. Flame heating applications are limited by inherent disadvantages—flame heating is surface heating; steep temperature gradients occur which sometimes boil away volatile constituents; and flame heating is difficult to restrict into sharply localized paths without excessive sacrifice in heat.

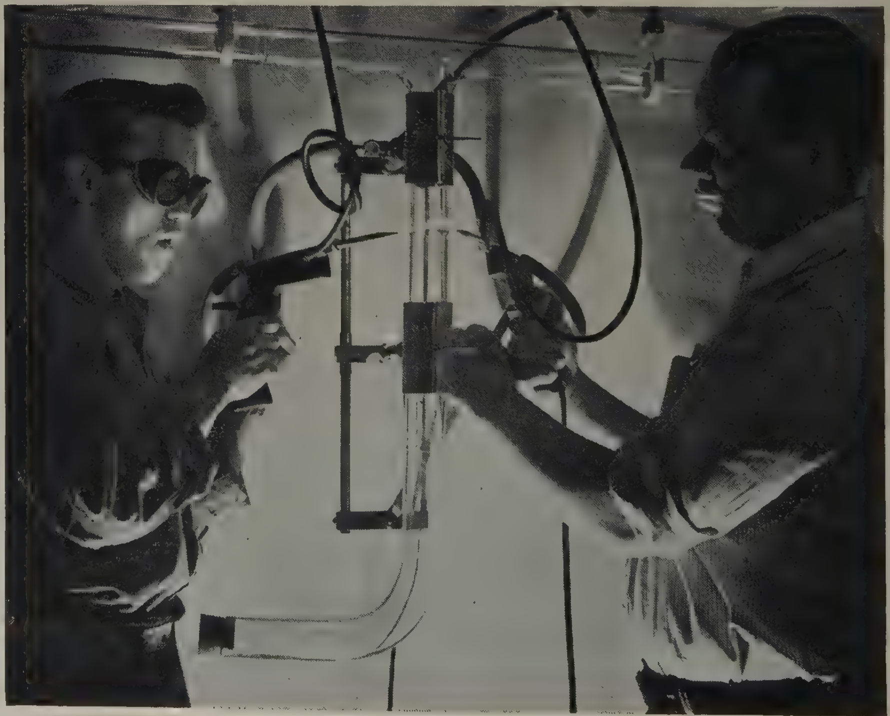
In contrast to the conventional flame-heating method, glass also can be heated by the transformation of some other form of energy into heat inside the glass. The electrical characteristics of glass are such that three different kinds of electric heating are applicable to glass working operations, each in a different temperature range.

At low temperatures (up to 600 degrees centigrade) where glass is an insulator, high-frequency dielectric loss heating is effective. A block of glass placed in a wave guide or between the electrodes of a capacitor and excited by high-frequency waves is heated by the periodic polarization of its molecules which results in inelastic distortions somewhat analogous to friction. This heat is proportional to the product of frequency of the electric field, the square of the voltage gradient across the glass to be heated, and

Based upon a conference paper, "The Welding of Glass With a High-Frequency Electric Torch," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948.

E. M. Guyer is a research physicist at the Corning Glass Works, Corning, N. Y

(Right) Field fabrication of a glass pipe line with a high-frequency electric torch and mobile wave generator. In typical field operation the pipe first is cut to proper length by encircling and squeezing the glass with a red hot electric wire loop. This is followed by sudden chilling with a wet pad. The glass breaks clean having good surfaces for welding. This same cutting operation is used to remove damaged sections from pipe lines for repair. The parts to be welded are clamped in accurate alignment on a sealing jig, provided with a toggle lever which serves both to press the hot pipe ends together to join them and then to pull them slightly while the operator blows into the pipe to remove the upset. After welding, split-cylinder electric heaters are closed around the hot glass joint to remove strains by timed annealing. Finally, polaroid spectacles and polarized light permit the pipe welders to inspect their work. Users report successful construction and installation of Pyrex pipe lines at less cost in man hours than equivalent installations of steel pipe.



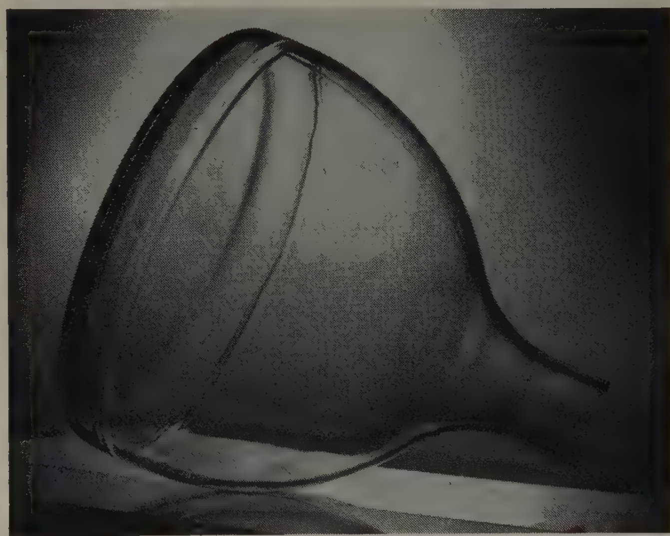
the loss factor or loss per cycle at unit potential gradient.

Once the glass has been heated from room temperature, where its resistivity is on the order of 10^{12} to 10^{19} ohms, to 400 or 500 degrees centigrade, where its resistivity has dropped to a few thousand ohms, the mobility of the positive metal ions through the interstices of the oxygen lattice is such that electric conduction heating is more practical than dielectric distortion heating. Here the rate of heating is expressed by the conventional forms of Ohm's law (I^2R or E^2/R).

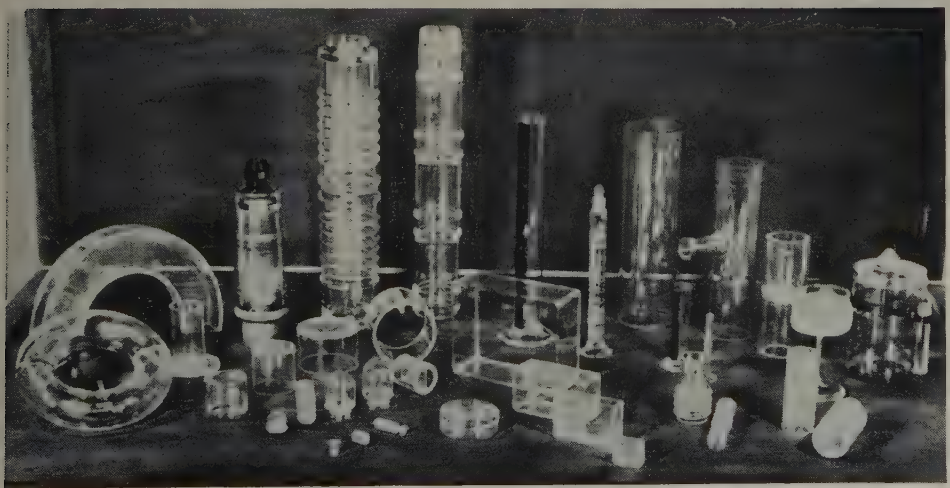
At still higher temperatures (1,200 degrees centigrade and up), soda lime glasses and other sufficiently conducting glasses rapidly can be melted and worked by induction heating as applied to metals and carbon products. Because the frequency necessary for effective induction heating is a function of the resistivity, glasses at elevated temperatures with resistivities measured in ohms require considerably higher frequencies than carbon with a resistivity on the order of milliohms and metals with resistivities measured in micro-ohms. The penetration of the current, however, is greater in hot glass in the same proportion. In terms of "skin effect," glass is a very thick skinned material indeed.

Of the three types of electric heating, electric conduction heating is least expensive and capable of the widest range of application. The electric-cross-fire, or the electric torch, is a powerful and versatile new tool for the glass worker which utilizes electrically conducting needle flames. Operations in both shop and field, as shown by the accompanying illustrations, demonstrate several advantages of electric glass welding over conventional flame sealing. Electric heating provides deep penetration into thick sections of high melting temperature glass. High temperatures can be attained rapidly without destructive boiling of the surface. Electric heat can be localized sharply leaving adjoining glass undistorted. More accurate temperature control is attainable and uniformity of results is better in repeated operations. Faster operation is possible because of the combined effects of more efficient heating and better localization which reduces the required volume of heated glass. As a result new glass products are manufactured to closer tolerances in the welding shop, and high melting temperature industrial glass structures are built with mobile welding units in the field.

(Above) An all-glass heat exchanger formed by electrically welding glass pipes to glass U-bands. In the atomic bomb plant at Oak Ridge, Tenn., more than seven miles of Pyrex pipe line was installed, requiring more than 35,000 glass cutting operations and the fabrication of more than 3,000 special pipe details.



(Above) Electric sealing machines weld near optical quality hard glass viewing panels to giant funnels with greater speed and higher selection than former methods.



(Left) The high-frequency electric torch performs old operations faster or more easily than conventional gas fires and makes possible new operations formerly too difficult to be practical. Glassware in current production by these novel methods ranges from miniature optical cells to large electric bushings and glass doughnuts for multimillion-volt electron accelerators. Such progress has been made in closely controlled heating with these electric sealers that even delicate instruments with motorized mechanical movements have been sealed up, undamaged, in glass globes. Here they have continued to operate for extended periods many times longer than their normal unprotected life. This introduces a new era in glass-bottled instruments sealed safely from dirt, moisture, and atmospheric attack.

A New A-C Bus Design

ROBERT N. WAGNER
ASSOCIATE AIEE

WHILE the conventional methods of bus distribution, using multiple cables, flat bars, channels, angles, or tubular conductors, all have their particular advantages, they are limited, chiefly because of excessive voltage drop or high installation cost. Industrial concerns continually are faced with this difficult problem in laying out the electric system for manufacturing plants. The ability of manufacturers to extrude high conductivity metals in practically any shape, opens up a new field to the designer for arrangement of conductors. By using close spacing in a partial triangular arrangement low reactance is obtained, in a simple and inexpensive structure. Using these developments, a new bus has been designed for loads of 2,000 to 5,000 amperes at voltages up to 600.

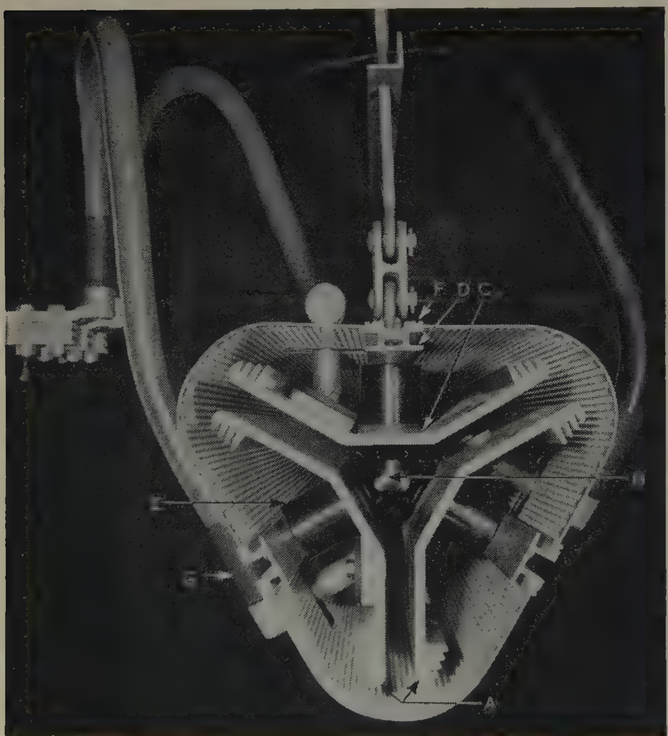


Figure 1. Section of bus in hanger support

A—Conductors
B—Three-phase insulator
C—Neoprene washer
D—Supporting member
E—Housing insulator
F—Groove
G—Tap

The final design of the new sector bus is shown in Figures 1 and 2. The three conductors *A* are extrusions of electrical conductor aluminum and for a 3,000-ampere design are approximately $12^1/_2$ inches wide by 11/32 inch thick. Forty-foot lengths have been used to date but longer lengths can be made. Each conductor has a cross-sectional area of 5.16 square inches and a perimeter of 33.86 inches. The width to thickness ratio was determined by calculations from Maxwell's basic formula for reactance, using geometric mean distances. The final design has a ratio of 36. This study also aided in deciding on a conductor spacing of one inch—a good compromise between low reactance, adequate cooling, satisfactory insulation, and reasonable short-circuit stresses.

The fins on the edges of the conductors were put on to aid in cooling, to increase stiffness, and to distribute the cross-sectional area efficiently. Such desirable modifications in shape are practical by the extrusion method of manufacture.

A suitable design of a 3-phase insulator *B* presented a number of interesting problems. It was imperative to get a satisfactorily large creepage distance combined with adequate strength for short circuit. The part also must be practical in cost and easily assembled. Both porcelain and phenolic resin have their particular advantages, but for this indoor design the latter material seemed preferable. After the design was worked out and the proper phenolic resin with its canvas filler selected, the part proved to be economical to form in ordinary molding presses and possessed very high strength. The unique shape gives a full two inches of creepage distance between phases with a small over-all size. The shape of the surfaces prevents excessive dust collection.

As an additional precaution against "tracking" of the phenolic resin, the insulators are dipped in insulating varnish and baked before assembly. An interesting feature is the molded-in aluminum alloy bolts. The molding company engineers advised against steel bolts because of the possible damage to the die if a bolt should be improperly aligned in it. A high-strength heat-treated aluminum alloy bolt was used, having a specially designed oval head rounded at all points to prevent stress concentrations in the phenolic resin. Samples of the completed insulators were checked for tensile strength. The 1/2-inch aluminum alloy bolt failed at the expected value of 8,500 pounds (68,000 pounds per square inch) without damage to the insulator. The special bolt head design which uniformly distributes the stress to the phenolic resin, contributes much to the over-all strength of the unit.

These bus insulators are located on 4-, 2-, or 1-foot intervals, depending on the short-circuit duty on the system. Preliminary tests have indicated that 1-foot spacing will withstand a short circuit of about 60,000 amperes

Essential substance of paper 48-16, "Features of a New A-C Bus Design," which was recommended by the AIEE industrial power systems committee and the AIEE technical program committee for presentation at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948; and is not scheduled for publication in AIEE *TRANSACTIONS*.

Robert N. Wagner is an electrical engineer with the Aluminum Company of America, Pittsburgh, Pa.

rms; 2-foot, about 40,000 amperes; and 4-foot, about 30,000 amperes.

Another important part of the design are the special neoprene washers *C*. These relieve the peak short-circuit stress considerably by allowing the conductors to move slightly. In a flexible system part of the short-circuit force appears as energy in overcoming the inertia of the conductor and in doing work on the flexible support. This movement produces a damping effect which reduces the peak force on the insulator bolt. The washer is three inches in diameter by 13/32 inch thick, and has a stiffness of about 65 durometer.

For several years many engineers have felt that better design and arrangement of conductors are needed to distribute large blocks of 3-phase a-c power. The refinement of extrusion methods has enabled the design and construction of a partial triangle bus arrangement which compares quite favorably with previous designs.

For present-day safety standards no bus assembly would be considered complete without an enclosure. The main supporting member is a lightweight aluminum alloy extrusion *D*. Fastened to these supports are perforated or solid aluminum sheets 1/16 inch thick by 12 feet long. These sheets are preformed in a brake. They are snapped into the supports and fastened at about 3-foot intervals with self-threading sheet metal screws. The small groove in the extrusion *F* centers the hand drill used to drill these holes. If, after the bus is installed, it becomes necessary to make taps, it is a simple matter to remove these sheets at any point.

The enclosure is supported from the bus at 10-foot intervals with simple cylindrical phenolic resin insulators *E*. Note that these housing insulators are not required to withstand any of the short-circuit stresses. This insulator has tapped holes in each end. One engages the bolt of the center or bus insulator. The other end takes an aluminum alloy stud which holds the housing in place. To allow for a variation in linear expansion between the bus and the enclosure, the support extrusion is punched with slotted holes. The elastic stop-nut is adjusted loosely against this support. To prevent the stud from turning in the insulator, a special washer (not visible in Figure 1) cut from an extruded shape is used. After the nut is adjusted, the ears of this washer are bent in slightly to form a lock.

Table I. Comparison of Various Methods of Transmitting 3,000 Amperes at 440 Volts, 60 Cycles, 3 Phases

	Sector Bus Assembly	6 4-In. Aluminum Channels (With Enclosure)	12 1,000,000-Cir-Mil Aluminum Cables (Open)	21 1,000,000-Cir-Mil Insulated Aluminum Cables (in Conduit)
Line-to-line voltage drop per 1,000-ft run, 100 per cent power factor	21.5	47.5	33.0	16.8
Line-to-line voltage drop per 1,000-ft run, 80 per cent power factor	41.6	123.2	62.0	30.0
Approx cost per ft installed, per cent	100	150	100	200
Approx weight per ft installed, lb	23	35	25	100
Approx space required, sq in.	180	360	220	240
Ease of making future taps	+	+	+	−
Safety to personnel	++	++	+	++

At points where the housing insulators do not occur, the neoprene washer, a flat steel washer, and an elastic stop-nut are used to make a rigid assembly with the bus insulator.

After erection, the conductor sections are spliced by the use of short aluminum bars of suitable size. Four 1/2-inch fine-thread high-strength steel bolts and four Belleville spring washers are used for each splice bar. Because standard nuts on these bolts would use too much of the clearance distance between phases and it is impractical to tap the conductor, a special high-strength steel spline nut was designed. The splines engage the aluminum and make a tight fit in an 11/16-inch hole. When first assembled, these spline nuts are pulled into the conductor by the splice bolts and thereafter remain part of it. They decrease the space between phases by only the thickness of the shoulder, which is 3/16 inch, and readily can be placed opposite each other. The high-strength bolt and spline nut develop the full 10,000-pound compressive capacity of the Belleville spring washers.

Expansion joints of laminated sheet aluminum are spaced at about 150-foot intervals. These flexible joints

Figure 2. Exploded view of component parts of a 6-inch section of the complete 3,000-ampere bus assembly

are attached to the conductor in the same manner as the rigid splice bars. A small section of cover is left off at the splices until the joint is made. The cover section then is snapped in place and fastened. However, in the instance of the flexible joints, a special larger section of cover is made so that it can telescope as expansion takes place.

Cable taps (Figure 1, *G*) are 1,000,000-circular-mil

aluminum cable argon arc-welded into a special cast aluminum lug which fits the contour of the bus. The same spline nut, bolts, and Belleville washer construction is used here, as at the splice plates. The lug extends through a hole in the enclosure. To close the hole around this lug, two pieces of special phenolic resin angle (not shown) are clamped around the lug to keep the enclosure verminproof. The flat surfaces allow taps to be made of any size and at any location found necessary, either during original installation or later as required.

INSTALLATIONS

Two sizes of the bus have been made and installed to date. These are conservatively rated at 2,000 and 3,000 amperes. The 2,000-ampere bus has an extruded conductor that is a smaller replica of the one shown in Figures 1 and 2. It is 1/4-inch thick by $8^7/_8$ inches wide and has an area of 2.82 square inches. Its perimeter is 23.6 inches. Other sizes can be made, but probably the practical limit in one assembly is about 5,000 amperes. Above this, the width of the conductor would become excessive, while increased thickness, beyond a certain point does not increase a-c carrying capacity appreciably. Below 2,000 amperes the economics for 60 cycles probably would not be in favor of the sector bus, however, because of favorable reactance, this bus does have a place in higher frequency distribution. In fact, one installation already has been made at 440 volts, 3 phase, 180 cycles, which has given very gratifying results.

Figure 3 shows an installation of the bus where some rather difficult turns and corners had to be worked out. Corners are made by using special corner splice plates. The corner splice plates are made from standard 3/4-inch by 3-inch aluminum bus bar. They are cut and argon arc-welded in a jig to any shape required.

PERFORMANCE

Preliminary short-circuit tests have been conducted on the bus assembly. Currents large enough to produce forces which broke the bus insulator bolt, have been applied without bending or deforming the conductors or damaging other parts of the assembly in any way.

Table I compares the performance of the sector bus with conventional bus conductors. Though based upon preliminary test, these comparisons show some interesting results which indicate that the sector bus assembly equals or surpasses most of the desirable characteristics of currently used indoor distribution methods.

Figure 3. Bus as it appears installed in an industrial plant

Feeder Voltage Regulator Accuracy Standards

W. E. BIRCHARD
MEMBER AIEE

IMPROVED ACCURACY of automatic feeder voltage regulators will permit increasing feeder load or increasing feeder length without exceeding specified limits for consumers' voltage under varying conditions of load, temperature, frequency, and so forth. To obtain maximum benefits in system design and operation from increased regulator accuracy, distribution engineers must know what limits of error to expect for their operating conditions. The standards for "Accuracy of Control Devices for Induction Voltage and Step Voltage Regulators," which have been included in the proposed revision of ASA *C57*, "Standards for Transformers, Regulators, and Reactors," will provide a practical basis for specifications. The purpose of this article is to aid distribution engineers in gaining a working knowledge of these new standards.

The proposed accuracy standards classify the errors into:

1. Errors in the potential supply and voltage regulating relay.
2. Errors in the current supply and line drop compensator.

For group 1, the principal sources of error, the recognized ranges of variation, and the reference values used in determining errors are as follows.

(*a*). Regulator position: maximum raise to maximum lower; reference, neutral position.

(*b*). Load current: zero to rated current at 80 per cent power factor lagging; reference, zero current.

(*c*). Ambient temperature: minus 30 degrees centigrade to plus 40 degrees centigrade; reference, plus 25 degrees centigrade.

(*d*). Frequency: plus and minus 0.25 per cent; reference, rated frequency.

(*e*). Reference voltage in potential control circuit is 120.

Test conditions such as voltage wave form (practically sine wave) and compensator setting (on zero) are specified, and it seems desirable to add a specification that the regulator supply voltage shall be held constant. Variation in band width of the voltage regulating relay is excluded by the standards, but should not be ignored in practical applications. Because the errors in group 1 may occur simultaneously, the "plus group error" is taken as the sum of the individual plus errors, and the "minus group error" is the sum of the minus errors. It is found that additional definitions are needed to obtain proper classification of errors as "plus" or "minus."

For group 2, the only recognized sources of error are variations in the magnitude and power factor of the load current. Tests are made at rated frequency and an ambient temperature of 25 degrees centigrade. Errors are determined for the mid-range settings of the resistance and reactance elements individually, and the error for combined resistance and reactance is taken as the algebraic sum of the errors for the individual elements. The algebraic sum method is found to yield only a fair approximation of the actual error, but it is the most practical method proposed thus far. The test procedure excludes compensator dial marking errors and includes only those resulting from compensator phase angle errors. Because only one combination of load current and compensator setting can be encountered at a time, the "plus group error" is taken as the maximum of the plus errors for resistance compensation alone, reactance alone, or for combined resistance and reactance. The "minus group error" is the maximum of the minus errors. These values represent about the worst errors likely to be encountered.

Single-phase regulators may be used on 3-wire 3-phase systems where the power factor angle of the regulator is either 30 degrees greater or less than the load power factor angle. Therefore, it is necessary to make three sets of all accuracy tests in both groups 1 and 2 which are influenced either by regulator power factor or by phase shift connections. A set of tests is made for each of three power factor angles, 6.87, 36.87 (0.80 power factor), and 66.87 degrees with corresponding phase shift connections.

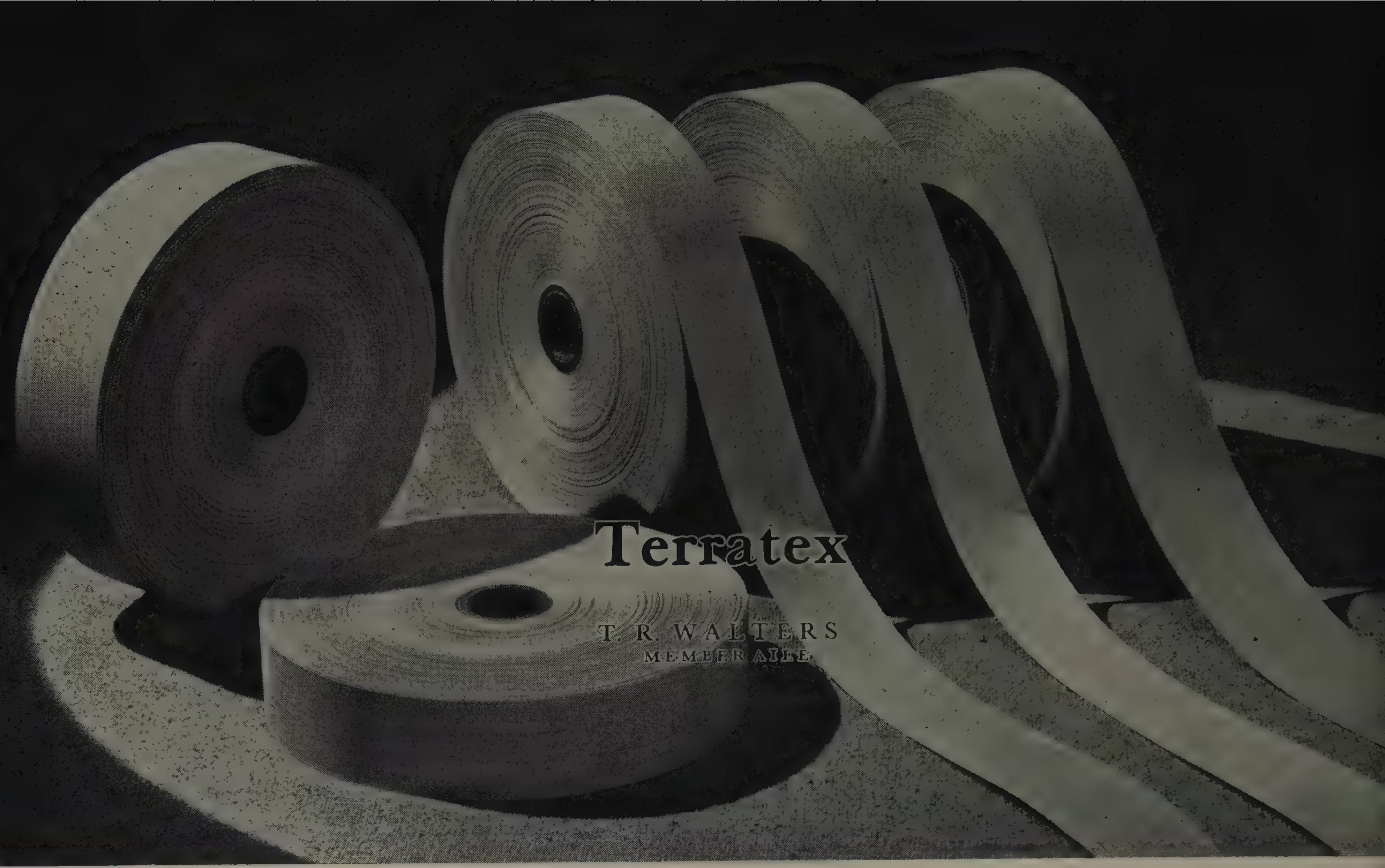
The standards define three accuracy classes in terms of maximum "over-all" errors of plus or minus one, two, and five per cent respectively. For each phase shift connection the over-all plus error is the sum of the plus "group errors" for groups 1 and 2, and the over-all minus error is the sum of the minus "group errors."

Testing technique is beyond the scope of this article. It merely is desired to emphasize the importance of extreme care and precision in measuring the accuracy of the first two classes of control equipment. Since the sum of the several errors must be less than one per cent or two per cent, each individual error must be much less, otherwise the errors indicated may be due more to errors in measurement than to errors in the apparatus tested. Many instrument problems will be encountered. For measuring voltage, accuracy at least equal to that of a "laboratory standard" type of voltmeter is required, and better accuracy is desirable. In measuring frequency errors it will be desirable to check several points over a range of several cycles and determine errors for the specified range from a carefully plotted curve. Really accurate measurement of power factor, or power factor angle, will be new to many laboratories.

The proposed ASA accuracy standards are not yet perfected, but they appear to offer a workable set of rules under which the industry can gain the experience necessary to improve them. They should provide a valuable aid in obtaining the desired economic benefits from the application of higher accuracy regulators.

Digest of paper 48-177, "Feeder Voltage Regulator Accuracy Standards," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

W. E. Birchard is with the General Electric Company, Pittsfield, Mass.



Terratex

T. R. WALTERS
MEMBER AIEE

Terratex is a thin flexible inorganic insulation manufactured from asbestos fiber. Its excellent high-temperature characteristics promise to make it an ideal inexpensive class *B* insulation.

One of the major factors which has limited the output rating of electric equipment has been the deterioration of organic insulations at high temperatures. To aid in obtaining higher ratings from the same size equipment, "terratex," an inorganic insulation, has been developed to take the place of certain commonly used organic sheet insulations.

To fill the everyday needs of the designer, a wide variety of organic sheets and tapes has been developed. The sheets are usually cellulosic papers and pressboards, whereas cellulosic fibrous materials take the form of yarns or woven tapes and cloths. Paper and pressboard are used as widely as possible because of their relatively low cost and excellent dielectric properties which result in good utilization of space. Yarns and fabrics are characterized by higher costs and poorer dielectric properties, consequently, they are used only where their better physical properties are required. Years of operating experience and laboratory tests have resulted in standardizing on a maximum temperature of 105 degrees centigrade for organic insulations, which are listed as class *A*.

In the class *B* insulation field, with a corresponding maximum temperature limit of 130 degrees centigrade, the designer is limited by the small number of useful materials. Mica sheets and tapes are expensive and often difficult to use. Commercial asbestos papers usually contain about 15 per cent of cotton fibers and starch, and are thick and weak dielectrically. Fiber glass yarns and cloths are excellent mechanically and thermally, but are fairly expensive and in themselves only spacers depending on varnish filling for dielectric strength. There has been no inorganic counterpart of the relatively low-cost high dielectric strength organic papers.

Consideration of the problem of providing an inorganic counterpart of organic paper led to the conclusion that a flexible inorganic sheet would require a fibrous base similar to that of the cellulosic fibers used in organic papers. Two inorganic fibers were known—asbestos and glass. Although neither fiber can be "hydrated" in the way cellulose fibers are in paper making, extensive experiments were made with both. At last, means were found for preparing asbestos fiber to much smaller dimensions, and for the removal of impurities and conducting particles to a degree not considered commercially feasible in the past. Means also were found for combining this purified fiber with the mineral binder and filler by a special paper-making process on fairly standard paper-making machinery. The resulting sheet, which has found a number of uses in electric apparatus, is thin, flexible, 100 per cent inorganic, and very similar in appear-

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Essential substance of technical paper 48-20, "'Terratex'—A Thin Flexible Inorganic Insulation," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

T. R. Walters is in the electrical research section of the laboratory of the General Electric Company, Pittsfield, Mass.

ance to cellulosic paper. All of the following data and uses are based on this asbestos-type material which has been named terratex.

PROPERTIES OF THE SHEET—UNTREATED

This new sheet has been produced as thin as one mil. Regular thicknesses are 1.5, 2, 3, 4, 5, 8, and 10 mils. So far, the greatest use has been for wire covering with the 3-mil material. During the past three years, an average of 66 pilot plant paper mill runs per year have been made of this thickness material for this purpose. The range and averages of thickness, tensile strength and dielectric strength for the three years are shown in Table I.

At present, the physical properties of tear and tensile strength, while not initially as high as those of commercial asbestos papers, are sufficiently high for effective use and extremely stable with time at high temperature. In aging tests such as are used widely on class *A* insulations, where the decrease in tensile strength is measured against time at various temperatures, no decrease is found in tests of many months duration. At 175 degrees centigrade, a temperature which reduces cellulose to a useless cinder in a matter of hours, terratex retained its original tensile strength after 710 days. Commercial asbestos paper containing the usual percentage of organic material had dropped 50 per cent to equal the strength of terratex in ten days and had lost 90 per cent of its initial strength in 87 days.

Besides being unaffected by long time exposure to the high temperatures it might be subjected to in electric apparatus, terratex is completely noninflammable. It can be brought to a bright red heat (850–950 degrees centigrade) in a Bunsen burner flame, with neither ignition nor melting of the sheet. In fact, it retains a dielectric strength in the order of 100 volts per mil at 800 degrees centigrade.

At room temperature the dielectric strength of this sheet is in the order of 300 volts per mil. Because of the drying out of absorbed water, this value increases to about 500 volts per mil at 300 degrees centigrade and gradually drops back to 300 volts per mil at 500 degrees centigrade. At this and higher temperatures the material becomes brittle in much the same way that "Muscovite" or white mica does, because of loss of the water of crystallization. Figure 1 compares these characteristics with those of other materials.

PROPERTIES OF TREATED TERRATEX

Although much better from both a thermal-life and dielectric strength standpoint than commercial asbestos paper, terratex at present is initially no stronger physically. This, coupled with the fact that this sheet can be made much thinner than commercial asbestos papers, makes the actual tensile strength in pounds per inch of width quite low. As all class *B* coils are given some type of varnish or compound treatment eventually for structural and moisture retardent reasons, the sheet generally is pretreated to facilitate handling. This treatment increases the tensile strength of the 3-mil wire covering type of terratex from an average strength of 300 pounds per square inch to a minimum of 4,000 pounds per square inch, which is more than ample for high speed wire covering. The varnish used can be one which previous experience has shown to be good for high temperatures, although no varnish available today has heat resistance equal to that of terratex sheet.

Varnished, the sheet naturally takes on some of the properties of the treating material. Dielectric strength tests have been made on alkyd, asphalt, phenolic, copolymer, and silicone-treated sheets. The results of three of these, on "burn out" dielectric tests run to the same temperatures as the all-inorganic untreated sheet, are shown on Figure 2. A minimum of varnish was used in treating these sheets. They were barely saturated, so that no surface film existed, as it was desired to limit dependence on organic materials to a minimum.

Treated cellulosic sheets carbonize and disintegrate when subjected to over-temperatures for a length of time. Terratex has been found to retain its naturally high initial dielectric strength when the treating compound is "cooked" out of it, while inorganic fabrics under the same conditions become merely "spacers" of low dielectric strength.

With loss of varnish, all flexible inorganic sheets including mica lose their initial moisture resistance. Table II shows the effect of moisture on lightly treated sheets of 3-mil terratex. Designers should note that the effect of water is greater on terratex than on the more familiar Kraft paper. Also, a better varnish will result in improved properties.

METHODS OF USE

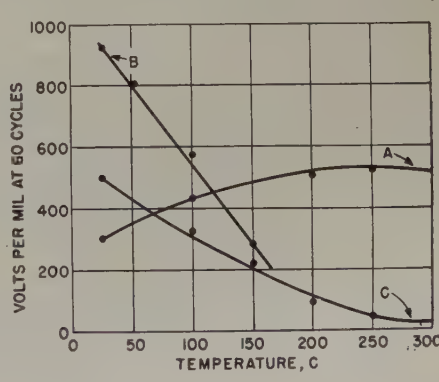
So far all manufacture and treatment of this sheet has been on a pilot-plant basis, so that its uses have been limited. The most important use has been on large magnet wire. Other uses are as layer insulation, mica backing, and as a mica substitute.

Magnet Wire. Pretreated 3-mil tapes have been applied to a wide range of rectangular wire sizes, from 90 mils square, up to large flat conductors. They were applied in two or more butt-wrapped layers in much the same way that paper tapes are used for much class *A* apparatus, except that they were "bonded" by applying an adhesive to the wire as the tape was wrapped on. In cases where the coil winding operation involved severe abrasion, an outer wrap of glass fiber was applied and varnished, corresponding to the cotton yarn that often is used over paper-covered wires for mechanical protection.

With a 12-mil build of insulation (six mils on a side) this terratex wire has a breakdown strength of 160 volts per mil or better. This compares with a strength of 60–80 volts per mil for felted asbestos wire, and of 80–100 volts per mil for varnished glass yarn wire, of the same insulation

Figure 1. Breakdown strengths of untreated terratex and other inorganic insulations

A—Untreated terratex. Two sheets 0.006–0.020 inch total thickness
B—Pyrex glass. 0.030 inch
C—Porcelain. 0.055 inch



thickness tested under the same conditions. The copolymer treated material was used for the wire insulation to obtain a good balance between electrical, thermal, and physical properties.

The copolymer treating material is an elastomer, and imparts a degree of stretch and tensile strength to the tape that makes it well adapted to wire covering. Such insulation yields when the wire is bent, instead of rupturing the way unstretching cellulosic papers do.

As the copolymer is also thermoplastic, consideration was given to what might happen to wires under short-circuit conditions, where high temperatures and high mechanical stresses occur simultaneously. Stacks of rectangular wire three high and three wide, were tied together and put through factory varnish treatment. They were prepared for rapid connection to a circuit applying 110 volts between adjacent turns, and then preheated to 175 degrees centigrade. When fully up to temperature, they were taken from the oven, placed immediately between the platens of an hydraulic press which were also at 175 degress centigrade and the connections made. The pressure then was increased gradually until an electric fault developed. This occurred at a pressure of 1,000 pounds per square inch, which was considered more than adequate.

Layer Insulations. Depending on such factors as the voltage between layers and the size of coil, any one of the available thicknesses of terratex may be used as a layer insulation for high temperature operation. The thinner sheets generally will require pretreatment to facilitate handling, although the 5-mil or thicker sheets either may be presaturated or used untreated and impregnated during the coil treatment.

In either instance, this new sheet makes it possible, through its inherent high dielectric strength, to obtain a high space factor with minimum dependence on varnish. If it is desired both to saturate and to coat the sheet with varnish, as some cellulosic papers are, higher dielectric strengths can be obtained. For example, a typical saturated 3-mil sheet has a dielectric strength of 400 volts per mil. Saturated and coated, the same sheet will have a strength of 600 volts per mil or more.

Table I. Range of Thickness, Tensile Strength, and Dielectric Strength Variation on Nominal 3-Mil Sheet "as Made"

Year	No. of Runs	Thickness, Mils Max	Thickness, Mils Min	Thickness, Mils Avg	Tensile Lbs/Sq In. Max	Tensile Lbs/Sq In. Min	Tensile Lbs/Sq In. Avg	Dielectric Strength, VPM Max	Dielectric Strength, VPM Min	Dielectric Strength, VPM Avg
1945	62	4.0	2.5	3.25	404	227	297	400	117*	304
1946	66	4.0	2 9	3.3	754	214	333	403	167*	313
1947	47†	4.0	2.7	3.3	413	214	332	407	185*	285

* Single lot—remainder well above 200 volts per mil.
† Not for complete year.

Table II. Effect of Moisture on the Short-Time 60-Cycle Dielectric Strength of Lightly Treated 3-Mil Terratex

Paper	Varnish	Thickness, In.	Dielectric Strength, Volts Per Mil 25 C	100 C	150 C	25 C wet
Kraft	Phenolic	0.0035	372	126	126	154
Terratex	Phenolic	0.0040		245	222	93
Terratex	Asphaltic	0.0035	421	448	368	195

Mica backing. Composite sheets of insulation often are used to fill the particular requirements of certain types of apparatus. Flexible mica generally has a sheet of thin organic paper pasted on each side to give it tensile strength and to hold the mica flakes in position. Despite its mica content, such a sheet is not satisfactory for temperatures so high that the cellulose disappears in time, leaving a loose structure.

To obviate this difficulty, thin varnished cloths of glass fiber have been used in place of the paper. This results in a sheet with excellent thermal life and physical properties, but of very high cost.

Replacement of one of the two 2-mil varnished glass cloths with a 1.5-mil varnished terratex on a flexible mica sheet which totaled ten mils, resulted in a composite of equal thermal life, a slightly higher and more uniform dielectric strength, ample tensile strength, and lower cost. A quantity of such sheets was used successfully during the war in certain very compact rotating equipment for aircraft. To save weight, this equipment was designed to operate at high temperature.

Mica substitute. Nominal 5-mil flexible mica sheets, particularly of the machine-made type, are quite variable in thickness (2–12 mils). At the thin spots the breakdown voltage is quite low. In comparison, 5-mil varnished terratex is a continuous, homogeneous class *B* sheet with a thickness variation of not more than 0.5 mil, and an equally uniform dielectric strength of about 400 volts per mil.

Comparative burn out tests with overcurrent have been made on windings with organic-backed mica and terratex used as insulation between layers. In time, the organic backing and the adhesive disappeared, leaving only the mica insulation. Under the same conditions, the terratex remained in position, providing practically the initial insulation.

Transformers. To gain experience with this new material, limited production use of it has been made. Starting in 1943, a number of arc-welding transformers has been built each year using terratex insulated wire. In addition, a smaller number of dry-type load center unit substation transformers of much higher voltage rating, has been built over the same time period. No service failures yet have been encountered.

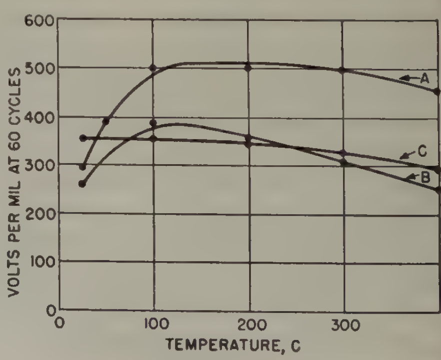


Figure 2. Breakdown strength of terratex with different resin treatments

A—Silicone-treated
B—Alkyd-treated
C—Copolymer-treated. Two sheets 0.007–0.022 inch total thickness

Salinity-Temperature-Depth Recorder for Sea Water

A. W. JACOBSON
ASSOCIATE AIEE

MANY physical phenomena in the oceans can be determined from measurements of the horizontal and vertical gradients of salinity and temperature. The "salinity-temperature-depth recorder" was developed to permit these measurements to be made continuously from a moving vessel. This type of instrument has been operated regularly for several years and has been found useful for obtaining hydrographic data. It has been applied particularly for inshore surveys in shoal water and in ocean areas where its accuracy of 0.2 degree Fahrenheit and 0.3 part per thousand ($^0/_{00}$) salinity are adequate. The instrument measures temperature over the range from 28 to 90 degrees Fahrenheit and specific electrical conductance from 0.00 to 0.07 mho, and from these computes salinity. Depth is measured over the range from 0 to 1,200 feet. The measured depth and temperature and the computed salinity are recorded simultaneously on a linear strip chart. The instrument operates from a 115-volt 60-cycle supply and is unaffected by normal variations in voltage and frequency and by the motion of the vessel.

Temperature is measured with a resistance thermometer bulb incorporated in a Wheatstone bridge. The circuit is compensated for lead length changes and for the nonlinear temperature-resistance characteristic of the bulb material. The error signal from the bridge is amplified by an electronic amplifier which operates a servomotor to restore the bridge to balance and to actuate the recording pen. To permit accurate measurements to be made rapidly, a bulb construction having high speed of response is employed, its time constant being 0.45 second.

Electrical conductivity is measured with a tubular cell through which the sea water passes. The cell forms one branch of a Wheatstone bridge, and the circuit is retained in balance by an amplifier and a servomotor.

The depth of the measuring elements is determined by measuring the hydrostatic pressure at that depth. A Bourdon element is used to position a contact on a slide-wire. By forming a bridge circuit with this slide-wire and another in the recorder, and employing an amplifier and servomotor, the position of the transmitter contact is reproduced in the instrument and depth is recorded on the chart.

The thermometer bulb, the conductivity cell, and the Bourdon element are mounted in a single assembly forming the "overboard" unit, and this is connected electrically to the recorder by a 9-conductor waterproof cable.

The computing method for determining salinity was selected over the simpler comparison method because it allowed the measurements to be made much more rapidly. In the comparison method a sealed reference cell containing sea water of known salinity is compared in a bridge circuit with the unknown sample. Provided the temperatures of both samples are the same, this bridge can be used for determining salinity. However, because of the slow thermal response of a sealed cell designed to withstand the hydrostatic pressure of 1,200 feet of water, this method is not well suited for use in a hydrographic instrument. With the computing method the measuring speed is limited only by the response time of the thermometer bulb, which can be made very short. From data relating salinity to temperature and conductivity a derived equation of the form

$$S=f_1(T)f_2(c)$$

is used, where S is salinity, T is temperature, c is electrical conductivity, and the f's represent specific functions of the variables. This form of equation is relatively simple to solve continuously by an electrical network. The specific functions are derived from nonlinear slide-wires mechanically coupled to the temperature and conductivity systems. These circuits are connected so that the output voltage is proportional to the product of the two functions, and thus represents salinity. This output voltage is measured by comparing it with a voltage derived from a linear slide-wire,

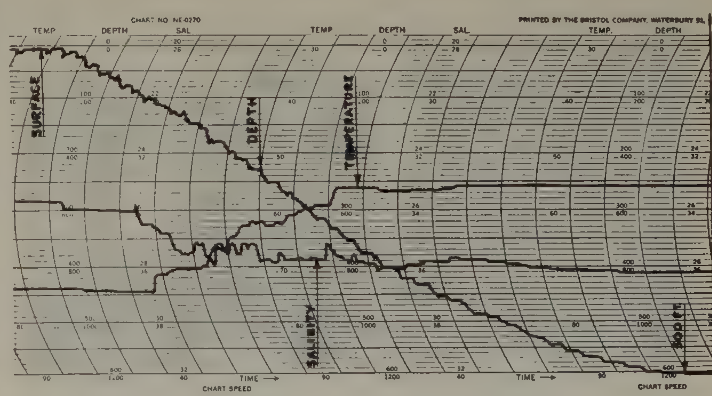


Figure 1. Vertical recording in ocean water

Latitude: 39°45′ N; Longitude: 70°45′ W; August 7, 1947, Balanus cruise number 10, STD number 1, depth scale 0–300 feet, salinity scale 28–40 $^0/_{00}$

using an electronic amplifier and a servomotor for maintaining a balanced condition and positioning the salinity recording pen. A switch associated with the network permits the selection of either of two salinity ranges: 20 to 32 $^0/_{00}$ or 28 to 40 $^0/_{00}$.

Figure 1 illustrates the application of the instrument to the study of complicated water structures.

Digest of paper 48-173, "An Instrument for Recording Continuously the Salinity, Temperature, and Depth of Sea Water," recommended by the AIEE instruments and measurements committee, and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

A. W. Jacobson is with The Bristol Company, Waterbury, Conn.

Electrochemical Sources of Electric Power—II

GEORGE W. VINAL
FELLOW AIEE

Part 2 of a 2-part article considering the subject of electrochemical power sources describes the technical aspects of the battery. Together with part 1, which presented an historical résumé of the electrochemical power source, this article constitutes one of a series of articles in *ELECTRICAL ENGINEERING* reviewing the various known and tried methods of producing electric power in the light of present-day knowledge.*

BATTERIES are typically electrochemical systems. Each cell of the battery consists of two dissimilar electrodes held apart from each other in a conducting liquid, called the electrolyte. These electrodes with their surrounding electrolyte, considered as individual systems, must differ in free or available energy and establish different potentials with respect to the electrolyte. Comparing one electrode with the other, the difference in potential between them is the electromotive force of the cell, neglecting other sources of potential difference which may or may not be present.

When the terminals of the cell are connected through an external circuit by a wire, the current that flows is proportional to the potential difference between the electrodes and inversely proportional to the sum of the resistances of the battery and of the external circuit. The current is transported through the electrolyte by charged particles, called ions, and through the metallic parts of the circuit by electrons. At the surface of the electrodes where the electronic conduction changes to ionic conduction chemical reactions occur.

The cathodic material constituting one of the electrodes is usually a chemical compound such as PbO_2, MnO_2, NiO_2, CuO, $AgCl$. These are the depolarizing materials. They are characterized by the ease with which they accept electrons; in so doing they are reduced to a lower state of oxidation.

Anodic materials are usually metals, such as Pb, Fe, Cd, or Zn. These are characterized by the ease with which they part with electrons, thereby dissolving to form positively charged ions in the electrolyte. This is an oxidation process.

Oxidation and reduction processes both are accompanied by chemical changes. There may be changes occurring in the electrolyte also. All of these changes take place in accordance with Faraday's laws of electrolysis. When the battery supplies electric current it is said to discharge. The chemical energy stored in the battery is converted into electric energy according to laws of thermodynamics.

The electrolyte, which provides ionic conduction between the electrodes, must be chosen with regard to the nature of the cathodic and anodic materials. In some types of batteries it serves primarily as an electrolytic conductor. For example, in the Edison nickel-iron storage battery, reduction of cathodic material (an oxide of nickel) and the simultaneous oxidation of the anodic material (iron) occurs without essential change in composition or strength of the potassium hydroxide solution. In the lead-acid storage battery, however, the sulphuric acid solution takes part in the chemical reactions occurring at both electrodes. The strength of the solution becomes impoverished as the discharge of the battery progresses. An excess of acid over that theoretically required is, therefore, necessary. Otherwise the electrolyte would become too highly resistant to the flow of electric current and undesirable changes in the reactions at the electrodes would occur.

Figure 1 relates to a 2-fluid cell of the Daniell type, but the principle is general. The accepted convention for the direction of flow of current in a wire and a battery dates from the time of Faraday. It perhaps would have been better if he had chosen the other way, but all is made consistent by the negative sign assigned to the electronic charge.

The rate at which chemical reactions occur depends on the rate of electron exchanges at the electrodes, and this in turn depends on diffusion, temperature, effective surface, and prevailing conditions of the electric circuit.

CHEMICAL REACTIONS—LEAD-ACID STORAGE BATTERIES

Double Sulphate Theory. The chemical reactions occurring in storage batteries (Figure 2), charge and discharge, have been a subject of dispute until recent years. Gladstone and Tribe[1] proposed the double sulphate theory in 1882 on the basis of their observations that lead sulphate is formed at both positive and negative plates during discharge and that the sulphate can be oxidized at one plate and reduced at the other during charge. Their theory is expressed conveniently by the equation

$$PbO_2 + 2H_2SO_4 + Pb \rightleftarrows 2PbSO_4 + 2H_2O \quad (1)$$

When the cell discharges the reaction proceeds to the right, but this is reversed during charge. The equation shows that the passage of one faraday of electricity (96,500 coulombs) in the direction of discharge results in the consumption of one equivalent each of PbO_2 and Pb and two equivalents of H_2SO_4 while two equivalents of lead sulphate and water are formed.

Part 2 of a 2-part article comprising essentially full text of a conference paper presented at the AIEE Midwest general meeting, Chicago, Ill., November 3–7, 1947.

George W. Vinal is chief of the electrochemistry section, division of electricity and optics, National Bureau of Standards, Washington, D. C.

* The following articles have been published in *ELECTRICAL ENGINEERING* on the subject of electric power sources: "Electrostatic Sources of Electric Power," by John G. Trump (*EE, Jun '47, pp 525–34*); "Nature and Use of Piezoelectricity," by W. G. Cady (*EE, Aug '47, pp 758–62*); and "Electric Power Sources," by L. W. Matsch and Wilbur C. Brown (*EE, Sept '47, pp 880–7*).

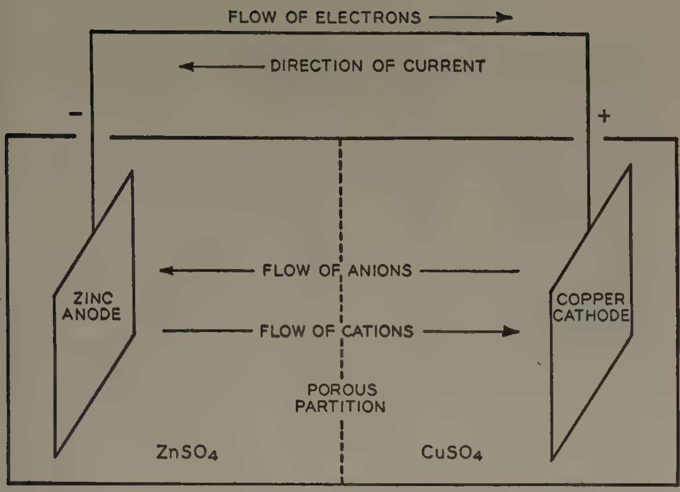


Figure 1. Relative flow of the ions, electrons, and the direction of current in a Daniell cell

Many attempts to determine the relation between the quantity of electricity passing through the cell and the materials formed or consumed are recorded in the technical literature, and diverse results led to many conflicting opinions. The key to the correct solution of the problem is a precise determination of the amount and concentration of the electrolyte at any stage of charge or discharge. This may seem easy to accomplish. Actually it is not and this is doubtless the reason for many erroneous experimental results of the past.

Craig[2] was the first to use a precise method for determining the acid consumption during discharge and by the same method to measure also the amount of water formed, which had not been done before. In principle his "method of mixtures" is based on the fact that if to a solution of measured concentration but unknown weight a carefully measured portion of water or another solution differing in concentration be added, and the resulting concentration determined, the weight of both the original and final solutions can be calculated accurately. It is of course necessary that the electrolyte be equalized completely throughout the vessel and the pores of the plates. Fortunately there are two tests for determining when this is accomplished. The first is by the constancy of electromotive force, which with care can be measured to one part in 20,000. The second method is by observing the approach of the concentration to constancy. Fifty to 100 hours may be necessary. The cell therefore must be free of appreciable local action. This can be attained by using pure lead grids (omitting antimony) and the cell must be protected from evaporation of water. Such a cell is stable for months.

Table I

Experiment Number	Equivalents Per Faraday: H_2SO_4 Consumed	Equivalents Per Faraday: H_2O Formed
9	2.07	1.56
10	2.00	2.14
11	1.99	2.25
12	2.01	1.89
Mean	2.02	1.96
Average deviation	±0.03	±0.19

Results of the last four experiments, for the sake of brevity, in which all precautions were taken, gave the results shown in Table I.

These data show that the theory of Gladstone and Tribe (equation 1) is consistent with the observed amounts of acid consumed and water formed when the cell is discharged. No assumptions regarding the correctness or applicability of any particular theory of chemical reactions were made, but their theory fits the facts and is confirmed by measurements to a higher degree of accuracy than before.

Thermodynamic Proof of the Theory. Having established the reaction, thermodynamic reasoning may be applied in comparing the heat of the reaction based on thermochemical data with calculations based on electrochemical data. The first involves no electrical phenomena and the second involves only electrical measurements. We are dealing with the transformation of one form of energy, chemical as represented by the heat of reaction, into another form of energy which is purely electrical.

The energy changes (heat of reaction) in a storage battery involve all of the constituents, including plates and changes in the heat content of the solutions. For the solids, definite values of the heat of formation are available and these do not vary with the concentration of the electrolyte. The variable factor depends on the concentration of the electrolyte, involving the partial molal heat content of the water and acid. From infinite dilution, where the relative partial molal heats are zero, to the other extreme of undiluted sulphuric acid, for which the acid has a value of 23.54 kilocalories per mole, the values are now available.[3]

A similar long and rather tedious series of computations

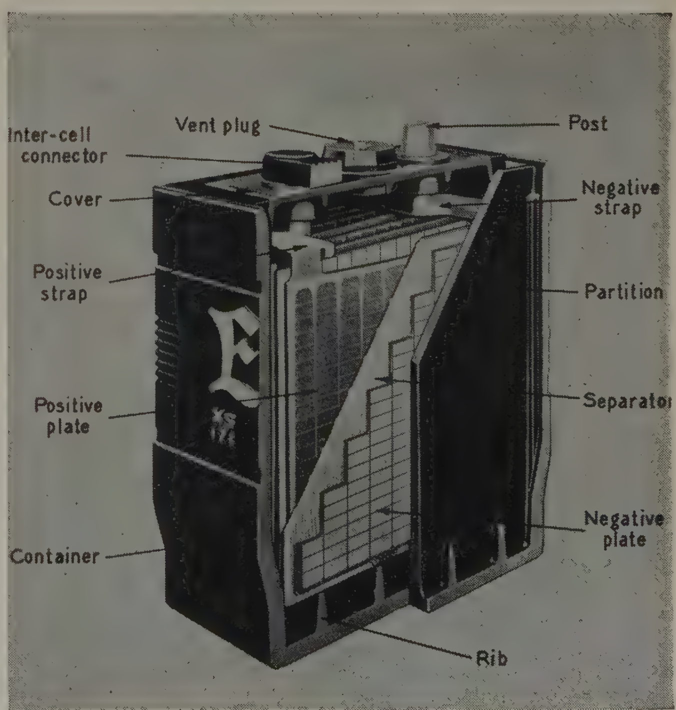


Figure 2. Lead-acid storage battery, showing the parts of one cell

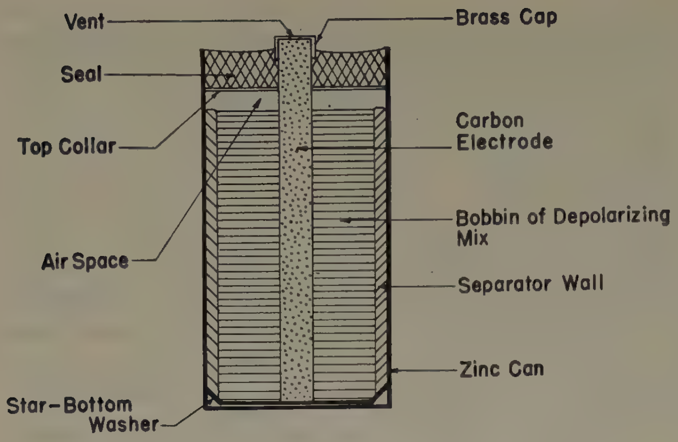


Figure 3. Diagrammatic cross section of a dry cell

is needed to obtain the heat capacity of the solutions. Details of these computations and the values for the entire range of acid concentrations from infinite dilution to the monohydrate acid are available to those who wish them. Only the final values for the heat of reaction can be given here, Table II.

Turning now to the electrical side of the problem, the thermodynamic relation between electrical measurements and the heat of reaction is expressed by the Gibbs-Helmholtz equation which may be written as follows:

$$\Delta H = -\frac{2\times 96500}{4.1833}\left(E - T\frac{dE}{dT}\right) \tag{2}$$

where ΔH is the heat of reaction in calories, E the electromotive force, T the absolute temperature, and $\frac{dE}{dT}$ the temperature coefficient. All of these quantities except ΔH can be observed and measured precisely. Of the numerical values, "2" represents the number of equivalents involved in the reaction, 96,500 is the value of the faraday constant in coulombs, and 4.1833 is the conversion factor to reduce the electrical measurements in volt-coulombs to calories. At the temperature 25 degrees centigrade the value of T is 298.16 degrees Kelvin. Substituting this in the foregoing equation, it becomes

$$\Delta H = -46136\left(E - 298.16\,\frac{dE}{dT}\right) \tag{3}$$

Table II gives the electromotive force and temperature coefficient as a function of acid concentration and in parallel columns the heat of reaction on the basis of electrochemical and thermochemical computations. The agreement is rather remarkable, considering the many possible sources of error. One fact seems clearly established, namely, that the equation for the double sulphate theory, must be correct. To have used any other theory than two equivalents each of H_2SO_4 and H_2O per faraday of electricity would have resulted in large discrepancies in the calculations.

CHEMISTRY OF DRY CELLS

Reactions in dry cells are rather more complex than those of lead-acid storage batteries, but much has been learned recently by the use of new and powerful tools of research, including the electron microscope, the X-ray spectrograph,

Table II

Specific Gravity $\frac{25C}{25C}$ Centigrade	Experimental Determinations: Sulphuric Acid (Per Cent)	Experimental Determinations: Emf at 25 Centigrade (Volts)	Experimental Determinations: $\Delta E/\Delta T$ (Mv/C)	Heat of Reaction: Electrochemical (Kilocalories)	Heat of Reaction: Thermochemical (Kilocalories)
1.020	3.05	1.855	(−0.05) *	(−86.28)*	−86.32
1.050	7.44	1.905	+0.15	−85.83	−86.53
1.100	14.72	1.962	0.29	−86.54	−87.44
1.150	21.38	2.005	0.33	−87.97	−88.87
1.200	27.68	2.050	0.30	−90.46	−90.99
1.250	33.80	2.098	0.22	−93.77	−93.65
1.300	39.70	2.148	0.18	−93.63	−96.51

* Based on electrode measurements because of impracticability of accurate battery determinations at 1.020 specific gravity.

the mass spectrograph, and the petrographic microscope.

In its ordinary form the dry cell, Figure 3, consists of a zinc can which serves the double purpose of anodic material and container; an electrolytic paste layer of gelatinized starch-flour mixture made into a paste initially with a solution of ammonium chloride (sal ammoniac) and zinc choride; a depolarizing mixture of manganese dioxide and graphite or acetylene black together with an excess of ammonium chloride.

The manganese dioxide is usually a natural ore obtained from the Gold Coast of Africa or an admixture with artificially prepared oxides. Textbooks commonly refer to the oxide as pyrolusite, but in recent years the various crystal forms of manganese ores have been distinguished by X-ray and electron diffraction. The new terminology is given in a paper by Fleischer and Richmond.[4] Five varieties of importance in dry cells, identified by McMurdie,[5] are pyrolusite, Ramsdellite (a dimorph of pyrolusite), cryptomelane, and two poorly crystallized, but valuable forms, δ-MnO_2 and γ-MnO_2.

Copeland and Griffiths[6] in one paper, and McMurdie, Craig, and Vinal[7] in another paper along somewhat parallel lines have followed by diffraction methods the changes in crystal structure as the cell discharges and both agree that the end product is hetaerolite, a double oxide, $ZnO \cdot Mn_2O_3$, which is isomorphous with Mn_3O_4, called hausmannite. The principal dry cell reaction, therefore, may be written:

$$Zn + 2MnO_2 \rightleftarrows ZnO \cdot Mn_2O_3 \tag{4}$$

The graphite or carbon black which is mixed with the manganese dioxide to form the depolarizing mix plays an important role notwithstanding the fact that it does not take part in the chemical reactions. Because manganese dioxide is a poor electrical conductor, graphite and carbon black greatly improve the conductivity of the mix. Acetylene black is particularly well suited to this purpose and in addition has unusual absorptive properties which enable the mix to hold more electrolyte. Mrgudich and Klock,[8] by the use of of X rays and the electron microscope, found that its unusual chain structure accounts for its good conductivity, absorption, and resiliency. At the present time dry cell manufacture, which reached its peak of production at the rate of three billion cells per year in 1945, is the largest single user of this commodity.

As a dry cell delivers current, the MnO_2 loses oxygen while zinc from the other electrode is oxidized. One can

consider the action as being essentially the addition of zinc oxide to the electrolyte. Using the petrographic microscope, McMurdie[5] found prismatic crystals of zinc diamine, $Zn(NH_3)_2Cl_2$ in the starch flour paste adjacent to the zinc electrode of undischarged cells. These are the "shelf life" crystals. In discharged cells basic zinc chloride, $4Zn(OH)_2 \cdot ZnCl_2$, crystals appear as small hexagonal plates.

Manganese dioxide generally is considered insoluble. Soluble divalent manganese does occur in acid solutions but nearly, if not completely, vanishes in basic solutions. Craig[7] investigated this matter in solutions ranging from pH of 1 to pH 10, a wider range than occurs in the dry cell. He found the change in potential is 0.12 volt per unit change in pH for the acid solutions up to a pH of 6, and 0.06 volt per unit of pH above. The cell normally operates from about a pH of 4 to higher values.

Various electrolytes other than ammonium chloride have been tried, including magnesium, calcium, lithium chlorides and the amine hydrochlorides of the methyl and ethyl series. The electromotive forces are not very different, but the behavior of the cells, that is, their output, resistance, and shelf life may be different. Obviously other important reactions than the principal reaction given occur during discharge or storage.

Gases emitted by dry cells are for the most part hydrogen, and except for confinement in closed containers, they may be disregarded. Hamer[9] made an extended investigation of the gassing of these cells, for which the mass spectrograph proved to be almost indispensible.

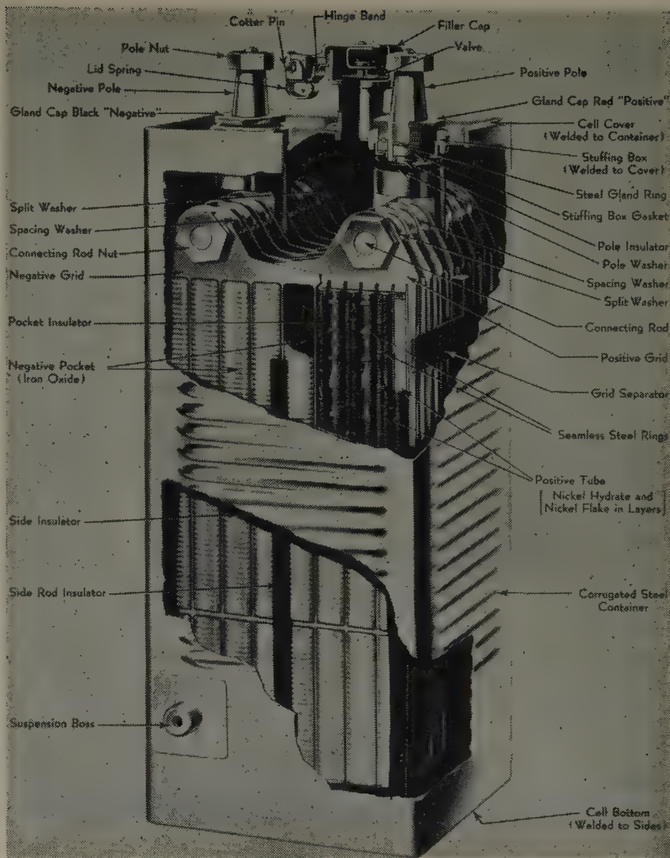


Figure 4. The Edison type of alkaline storage battery

AIR DEPOLARIZED BATTERIES[10]

The "air cell" battery is a primary battery consisting of a caustic alkali electrolyte, an anode of amalgamated zinc, and a large porous carbon electrode which has been treated with a water repellant. Atmospheric oxygen penetrates this carbon and is an effective depolarizer at the surface of the carbon electrode, where it is in contact with the electrolyte. It is important that the electrolyte should not penetrate the pores of the carbon. This will not occur if excessive current drains or too low temperatures are avoided.

These cells find use for operating telephone transmitters, emergency lighting, flashing signals, radio receivers, and so forth.

The initial voltage per cell is about 1.30 volts, decreasing to a nearly steady value of 1.25 to 1.20 volts throughout most of its service life. The maximum current rating of the usual type is 660 milliamperes at a terminal voltage of 1.25 volts per cell. Intermittent service is preferable. Batteries are available in 1- or 2-cell series connected construction. The capacity obtainable at light loads is 325 or 700 ampere-hours, depending on the size of the cell.

ALKALINE STORAGE BATTERIES

The Nickel-Iron (Edison) Type. The alkaline type of storage battery (Figure 4) familiarly is known in the United States as the Edison storage battery.[11] It is used in trucks, tractors, mine locomotives, miners' lamps, railway car lighting, and the like, services in which lead-acid batteries also find use. The Edison battery differs, however, from lead acid batteries in materials, construction, and in some electrical characteristics.

Edison began his work of perfecting this battery in 1900, but it was not until 1909 that the first Edison battery was placed in actual service. It was Edison's idea to make the plates of an assembly of perforated metallic containers in which the active materials could be packed. This is the construction used at the present time, practically unchanged since he approved the design in 1909.

The active material of the positive plate is nickel hydroxide, which subsequently is transformed electrolytically to a higher oxide of nickel. The hydrate, and flake nickel to improve its conductivity, are loaded in alternate layers into perforated steel tubes which are formed of spirally wound nickel-plated steel ribbon and reinforced by rings. The flake nickel consists of tiny squares 1/16 inch on the edge and 0.00004-inch thick, made by an electroplating process. In its final state a bushel of this material weighs only $4^1/_2$ pounds. Thirty tubes are joined to make the standard *A* plate.

The negative active material is a mixture of finely divided metallic iron, ferrous oxide, and a small amount of yellow oxide of mercury. This is packed into perforated steel pockets, 24 of them to the *A* plate.

The electrolyte is a 21 per cent solution of potassium hydroxide to which a small percentage of lithium hydroxide is added, more for practical than for theoretical reasons. The electrolyte does not change appreciably in composition during charge or discharge of the cell, but it does require re-

placement at infrequent intervals when it has become weaker or contaminated with carbonates.

The plates of Edison cells are well standardized on the basis of the *A* plate, which has a capacity of 37.5 ampere-hours at the 5-hour rate of discharge. The *B* plate has half of this capacity, the *C* plate $1^1/_2$ times, and the *D* plate twice the capacity of the *A* plate. There are also smaller and thinner plates.

At the 5-hour rate the initial voltage of a fully charged battery is about 1.40 volts per cell; the average voltage 1.20 and the final voltage 1.0 volt. At higher rates of discharge practically the full capacity can be realized, but at lower operating voltages.

Nickel-Cadmium (Jungner) Type.[12] This type of alkaline storage battery seldom is seen in the United States, although limited production has been undertaken. In Europe the battery has found more extensive use.

The type of construction is similar to that of the Edison, but the positive plates usually consist of flat pockets instead of the spirally wound tubes. The active materials of the positive plates and the electrolyte are essentially similar to the Edison cell, but the active material of the negative plates is a mixture of cadmium and iron. The latter has some beneficial effect, but the real function of the iron is not entirely clear.

Operating voltages on discharge are about the same as for the Edison cells, but on charge the characteristic curve has a somewhat different shape.

During the war the Germans made a flat sintered-plate type of nickel-cadmium battery.

THE COPPER OXIDE PRIMARY CELL[13,14]

Known generally as the railway signal type of primary battery, the copper oxide cell is the modern development of the Lalande cell of 1883 and its improvement by Edison and others. It consists of a depolarizing electrode of cupric oxide and a negative electrode of amalgamated zinc. The electrolyte is a solution of sodium hydroxide topped with a thin layer of oil to prevent evaporation and the absorption of carbon dioxide from the air.

The railway type usually is assembled in a barrel-shaped heat-resisting glass jar. The ampere-hour capacity is 600 or 1,000, but smaller sizes are available also. The closed circuit voltage is about 0.6 volt per cell, but there is a modification having slightly higher voltage.

This battery finds its principal use for railway signaling, track circuits, crossing bells and lights, but it has excellent characteristics for laboratory use.

OPERATING CHARACTERISTICS—LEAD-ACID BATTERIES

The operating characteristics of lead-acid batteries is too large a subject to be covered adequately within the limits of this article. However, a few salient points may be mentioned.

Discharge output of a battery normally will exceed the manufacturer's rating until near the end of its service life, which may be specified as 80 per cent of rated capacity. Ratings usually are based on discharge for some specified period, as 5 hours, 20 hours, and so forth. A battery which will deliver 5 amperes for 20 hours is said to have a capacity of 100 ampere-hours, but it cannot deliver 20 amperes for 5 hours. The capacity decreases as the rate of discharge increases. The relation of current and time may be expressed by the equation

$$I^n t = \text{a constant (the capacity)} \qquad (5)$$

in which I is the current; n, a constant for the type and kind of battery, ranging from about 1.3 to 1.5. Estimates of the capacity at various rates are made conveniently from linear plots on log-log paper or by slide rules.

Temperature has an important effect on discharge characteristics because the resistivity and viscosity of the electrolyte increase as the temperature is decreased. The first produces a greater *IR* drop within the battery and the second decreases the rate of diffusion of electrolyte into the pores of the plates, which has a like effect of reducing the working voltage. A third reason for limited capacity at low temperatures is freezing. The freezing point varies with the concentration of the electrolyte, which becomes more dilute in the pores of the plates as discharge proceeds. Localized freezing in the plates may occur before the main body of electrolyte freezes.

The working voltage falls gradually as discharge proceeds until the concentration in the pores of the plates has diminished to the point beyond which the rate of discharge no longer can be maintained. This occurs at about 1.70 volts for normal rates, but a lower value for the "end point" should be chosen for high rates of discharge. After a period of rest during which diffusion occurs, further discharge may be made. Some gassing occurs during discharge or idle periods as a result of local action. Ventilation is always necessary.

Charge is accomplished by applying an electromotive force slightly in excess and opposite in polarity to that of the battery. If the difference is very small the battery is said to "float" on the charging line. An increased difference between the applied electromotive force and the battery's counter electromotive force results in a larger charging current. If the current is held constant, the counter electromotive force of the battery as measured by the voltage at its terminals rises gradually until the number of ampere-hours supplied substantially equals the ampere-hours previously discharged. At this point more rapid increases in voltage and temperature ensue. The charging current normally is reduced to a specified "finishing rate" at this point.

However, if a suitable voltage is applied at the terminals of the battery and is held constant, the charging currents will begin at a high value and taper off as the state of charge increases. This property of a battery to absorb electric energy at very high rates when in a discharged state is most important, but often misunderstood. To avoid excessive temperatures and gassing as well as to obtain the best efficiency, the rate of charge at any time should not exceed the limits set by the "ampere-hour law."[15] That is, the charging rate in amperes at any time, *t*, should not exceed the numerical value of the ampere-hours at that time lacking for a full charge. For example, if a battery has been discharged 200 ampere-hours, the initial charging rate may be 200 amperes or less, but the charging current must be

reduced progressively as time goes on to keep within the provisions of the law. This is an empirical law, but a very useful one. With proper choice of the applied constant potential, charging becomes for the most part automatic, because the counter electromotive force of the battery rises as charge proceeds and this automatically decreases the charging rate. If the law is followed as closely as possible, 50 per cent of the total charge may be supplied in about 40 minutes, 75 per cent in one hour and 20 minutes, 90 per cent in two hours and 20 minutes. When the current has fallen to the so-called finishing rate of the battery, this can be continued without further reduction. The applied voltage for constant potential charging is from 2.15 to 2.35 volts per cell, depending on the service to be rendered.

When the battery is connected directly to the bus, charge or discharge occurs according to conditions at the moment. For example, aircraft batteries of 12 cells are connected to a 28.5-volt bus. Temperature plays an important role. At very low temperatures a higher bus voltage is needed to charge the batteries at satisfactory rates, and too high voltages at high temperature lead to the so-called "vicious cycle." That is, the current first decreases to a minimum and then rises again as the battery is warmed. This is a condition of instability.

Stability is attained in the modified constant potential method of charging which is used very generally for batteries in motive power service. The voltage of the charging bus is necessarily higher than for straight constant potential charging as a small fixed resistance is included in the circuit. The initial charging rate is lower, the final rate higher and the time somewhat longer than for the straight constant potential charge.

For a more complete discussion reference should be made to the paper by Woodbridge.[15]

Newly installed equipment for automatic cycling of storage batteries while on test is shown in Figure 5.

OPERATING CHARACTERISTICS OF DRY CELLS

Standard Tests. The new American Standard specification for dry cells and batteries, *C18*-1947,[16] was approved by the American Standards Association on August 6, 1947. This specification was prepared by a committee which included representatives of the industry, large industrial users of batteries, and several of the Government departments. It covers a wide variety of sizes and types of dry cells and batteries, including miniature cells recently developed.

All of the cells listed in Table III are cylindrical in form, but cells of other forms, such as flat cells, may be used in batteries, subject to specified output and dimensions for the particular battery.

Dry cells and batteries are subject to tests which should simulate working conditions. The test which best represents any particular service is that which most nearly duplicates the rate of energy output of the battery when in actual use. There is no direct relation between the results of continuous tests and intermittent tests of longer duration.

Because dry batteries ordinarily are tested on circuits of constant resistance, the results usually are expressed as the time of discharge rather than as the capacity in ampere-hours. The ampere-hours can be calculated, however, by determining the average value of the current.

The useful output of dry cells has been improved greatly as the art of making them has progressed. The following are a few examples taken from a paper by Gillingham.[17] Shelf deterioration occurring in 6 months (no. 6 cells) was reduced from 35 per cent in 1901 to 7 per cent in 1934. The useful output of telephone cells increased from 155 days in 1910 to 360 days in 1930. Radio *B* batteries, which appeared about 1918, gave 377 hours service on a particular test, not used now, but this was increased to 1,500 hours in 1934. These improvements came about as a result of skill in manufacturing, different and better sources of natural ore, limited use of artificial oxides, and the introduction of acetylene black.

A few examples of test results obtained on batteries made in 1946 are given in Table IV. These are average results of various brands that complied with the minimum requirements of the specifications.

Table III. Standard Sizes of Cylindrical Dry Cells

Cell Designation	Nominal Dimensions: Diameter (Inches)	Nominal Dimensions: Height (Inches)	Approximate: Volume (Cubic Inches)	Approximate: Weight (Pounds)	Principal Uses
AA	17/32	1 7/8	0.42	0.033	Flashlights, radio, and miscellaneous
A	5/8	1 7/8	0.57	0.045	Radio *B* batteries
BF	3/4	1 5/16	0.58	0.046	Flashlights, and export
BR	3/4	1 1/2	0.67	0.054	Radio *B* batteries
B	3/4	2 1/8	0.95	0.077	Radio *B* and *C* batteries
C	15/16	1 13/16	1.25	0.10	Flashlights
CL	15/16	2 5/8	1.81	0.14	Hearing aid batteries
CD	1	3 3/16	2.51	0.20	Hearing aid batteries
D	1 1/4	2 1/4	2.76	0.22	Flashlights and radio *B* batteries
E	1 1/4	2 7/8	3.52	0.28	Portable telephones
F	1 1/4	3 7/16	4.22	0.35	Railroad lantern, group Radio *A* and heavy duty *B* batteries
G	1 1/4	4	4.92	0.40	Radio *A* and heavy duty *B* batteries
J	1 1/4	5 7/8	7.20	0.60	Group and radio *A* batteries
No. 6	2 1/2	6	29.3	2.2	Telephone, ignition, and general purposes
Miniature Cells					
R	17/32	1 5/16			Radio *B* batteries
P	17/32	1			Radio *B* batteries
N	7/16	1 1/16			Radio and hearing aid *B* batteries
NS	7/16	3/4			Radio and hearing aid *B* batteries
U	5/16	1/2			Radio and hearing aid *B* batteries

Table IV. Average Output of Brands Complying With Requirements

Type of Battery	Size of Cell	Kind of Test	1946 Measured Output	Requirement of ASA Specification
Flashlight	AA	4-ohm intermittent	85 min	65 min
Flashlight	C	4-ohm intermittent	359 min	300 min
Flashlight	D	4-ohm intermittent	843 min	625 min
Industrial cell	D	Light industrial	1,071 min	850 min
Special telephone	No. 6	3 cells 20 ohms, intermittent	403 days	325 days
Hearing aid	CD	*A* battery test	66.2 hr	60 hr
Hearing aid	N	*B* battery test (light)	1,120 hr	800 hr
B batteries	D	1,250-ohm test	360 hr	300 hr
B batteries	B	2,500-ohm test	256 hr	210 hr
B batteries	N	5,000-ohm test	110 hr	75 hr

Effect of Temperature. Low temperatures have a marked effect on the output of dry cells. In a paper published in

1922[18] it was shown that dry cells become practically inoperative at a temperature of −21 degrees centigrade (−6 degrees Fahrenheit). More recent determinations have confirmed this conclusion, but there is some variation among different makes and types of cells. Depending on the requirements, some cells may be usable a few degrees lower.

The electromotive force of the dry cell, that is, the true open-circuit voltage, decreases about 0.02 volt when the temperature is decreased from 25 degrees centigrade (77 degrees Fahrenheit) to −20 degrees centigrade (−4 degrees Fahrenheit). That is, the decrease averages 0.0004 volt per degree centigrade. This is slightly more than for a lead storage battery. However, the open-circuit voltage usually is measured by a voltmeter which draws a small current from the cell and the effect of temperature on the electromotive force may appear to be greater.

For practical purposes the actual working voltage at the terminals of the cell or battery under specified conditions of load and temperature is of more significance than the electromotive force. Table V shows the results of measurements on a cell of size *F* under such conditions.

Table V. Initial Voltages of a Dry Cell, Size F, Under Varying Conditions of Temperature and Current Drain

Temperature		Terminal Voltage at Indicated Drains			
C	F	0.020 Amp	0.050 Amp	0.075 Amp	0.10 Amp
30	86	1.641	1.632	1.621	1.612
20	68	1.637	1.624	1.613	1.603
10	50	1.634	1.620	1.605	1.592
0	32	1.631	1.614	1.595	1.581
−10	14	1.627	1.605	1.584	1.564
−20	−4	1.61	1.59	1.56	1.54
−30	−22	1.49	1.28	1.10	0.96

Decreased flash current at low temperatures is the result of increased resistance of the cells. The internal resistance of a battery varies somewhat with the rate of current discharged. For the present purpose it is defined in terms of the flash current. The formula is $R=\frac{E}{I}-0.01$ where R is the resistance of the cell, E its electromotive force at a specified temperature, I the flash current, and 0.01 the resistance in ohms of the external measuring circuit. Table VI gives the average result of measurements on 12 no. 6 cells of six different brands.

Table VI. Internal Resistance of Dry Cells (Flash Current Method, Average of Several Brands)

Temperature		No. 6 Cells		Size D Cells	
C	F	Average Resistance, (Ohms)	Percentage of R at 25 C	Average Resistance (Ohms)	Percentage of R at 25 C
40	104	0.033	87	0.195	86
30	86	0.036	95	0.214	94
20	68	0.041	108	0.246	108
10	50	0.049	129	0.291	128
0	32	0.061	161	0.362	159
−10	14	0.077	203	0.493	217
−20	−4	0.144	379	1.551	684
−30	−22	1.5	4,000	15.6	6,900
−40	−40	15.0	40,000		

Figure 5. Three of six battery banks installed at the National Bureau of Standards for the complete automatic control of charging and discharging storage batteries while on test

Each bank is provided with two motor generators, operating in parallel, to supply the charging current. Maximum capacity is 500 amperes at 30 volts direct current for each bank

The effect of temperature on the capacity of dry cells is large. Capacity depends also on the load and cut-off voltage. Even at light loads the available capacity at 70 degrees Fahrenheit to 1.0 volt per cell is cut about in half at 20 degrees Fahrenheit. For heavier loads or higher cut-off voltages the effect is much greater.

NEW TYPES OF BATTERIES

The Perchloric and Fluoboric Acid Batteries. Improved utilization of lead dioxide over that in lead-acid storage batteries, particularly at low temperatures, is realized by using electrolytes in which the lead salts formed as a result of discharge are freely soluble. Previous efforts to substitute perchloric acid as an electrolyte in batteries of the usual lead-acid type have not been successful. The reason lies in the unusual nature of the plates which are required.

Nonporous active material of both positive and negative plates is necessary. This is contrary to the high porosity desired in ordinary storage batteries. For the perchloric or fluoboric acid battery (Figure 6),[19] the lead dioxide is electroplated from a lead nitrate bath as a solid mass on some underlying grid, such as nickel. The negative plate may be sheet lead or electro-deposited lead.

The chemical action is entirely from the outer surface of these electrodes. The reaction which takes place is expressed by the equation

$$\mathrm{PbO_2+4HClO_4+Pb \rightleftarrows 2Pb(ClO_4)_2+2H_2O} \qquad (6)$$

This equation indicates reversibility, but this is limited by "treeing" on the charging portion of the cycle. For practical purposes this is a primary battery which must be activated by filling it with electrolyte when required for use.

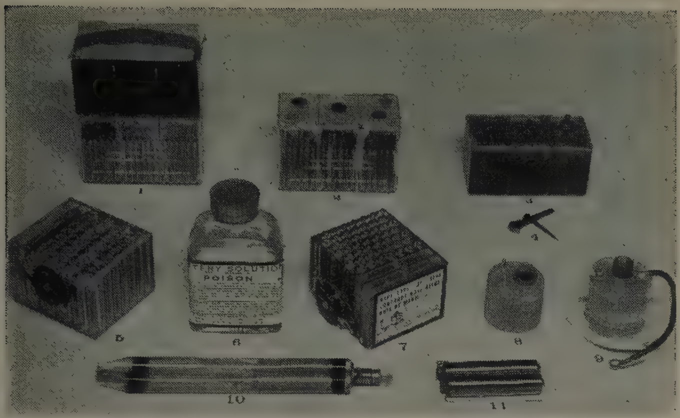


Figure 6. Several forms of the perchloric acid and fluoboric acid batteries with their reservoirs of electrolyte

However, it may be stored in the dry state indefinitely without deterioration.

The electromotive force varies with the concentration of the acid. The best value for any particular purpose usually is chosen with regard to the temperature and current drain of the contemplated use. Thus for use at -50 degrees centigrade the best electrolyte will be about 50 per cent acid. The electromotive force at this concentration of perchloric acid is 1.92 volts per cell and for fluoboric acid 1.86. The concentration of perchloric acid should never exceed 70 per cent. Perchloric acid is potentially hazardous. It should not be used ill advisedly. The fluoboric acid is safe and desirable, but the cells have a slightly lower watt-hour capacity. Fluosilicic and some of the sulphonic acids have been tried, but less successfully.

Figure 6 shows several small types of these batteries. Number *2* is activated from the reservoir, number *3*, mounted on it as in number *1*. Number *5* is an *A-B* battery, 3.6 volts *A* and 90 volts *B*. Its 51 cells are filled simultaneously from the bottle of electrolyte, number *6*, for which a special device to evacuate the cells is supplied. Numbers *8* and *9* are filled by pressing the button, which breaks a diaphragm separating reservoirs from the plates. Number *10* is filled by breaking glass ampoules within the plastic tubes which house both the reservoirs and plates. Number *11* is filled by a pipette.

The equivalent number of watt-hours per kilogram at the 5-hour rate for battery 2 is 46, which exceeds that of the more familiar batteries. The battery cannot stand indefinitely after filling. It must be used within a few hours, or at most a few days, when activated.

Silver Oxide Batteries. Silver as an oxide or halogen compound has been proposed as the active material of positive plates many times during the past 45 years. The object was apparently to provide a storage battery which should have larger capacity per unit of weight than the existing lead-acid types. Silver storage batteries, however, have found little, if any practical use. Their inherent defects are

1. Appreciable solubility of silver oxide.
2. Crystallization difficulties with the zinc negative electrode.
3. The ease with which the oxide is reduced by traces of organic matter.
4. The cost of the silver.

The point of departure in technique of the present day is to consider the silver cell as a primary battery[20] to be activated at time of use and to be used completely within a relatively short period of time. It is capable of very high rates of discharge and it provides an unusually flat voltage characteristic throughout its discharge.

A cell of this type comprises silver oxide positives, zinc negatives, and a solution of potassium or sodium hydroxide. The conductivity of the former is better, but zincates are more soluble in the latter.

The positive plates are prepared by pasting silver chloride or oxide Ag_2O on silver-plated copper screen. The silver compound then is dried and subsequently reduced electrolytically to sponge silver. Formation by anodic oxidation in a dilute solution of potassium hydroxide produces the peroxide of silver, Ag_2O_2. The amount formed depends on the current density, the percentage being higher at low current densities.

The zinc electrode may be sheet zinc or electroplated zinc on copper screen.

The chemical reaction has not been determined definitely but it is believed to take place in accordance with the equation

$$Ag_2O_2+4KOH+2Zn \rightleftarrows 2K_2ZnO_2+2H_2O+2Ag \tag{7}$$

Theoretically, the electrical output in watt-hours per pound of the silver oxide-zinc-alkali system is about double that of the lead-acid system. White, Pierce, and Dirkse reported 88 watt-hours per pound (theoretical) for the complete cell. The efficiency, however, varies with the rate of the previous charge and other factors. It may vary from 30 to 80 per cent.

The electrode characteristics of silver oxides measured against zinc (that is, cell voltages) are shown in Figure 7. These data were obtained by Craig, and reported in Denison's paper.[20]

X-ray examination of the positive active material shows definite evidence that the peroxide, Ag_2O_2, differs in crystal structure from the ordinary oxide Ag_2O.

Limitations to the shelf life of the cell depend on the extent of the solubility of the oxide and its subsequent reduction by hydrogen, evolved as a result of local action at the zinc. However, some cells packed with asbestos retained 70 per cent of initial capacity after two months storage at 54 degrees centigrade. Organic matter, including the more insoluble plastics, results in reduction of the silver oxide.

Silver Chloride Cells. Another type of silver battery was developed during the war to meet the need for a lightweight high-powered battery. This is the silver chloride battery,[21] which must be preserved in a dry state until required for use. At that time it is activated by immersion in either salt or fresh water. To prevent premature activation the cells are preserved in hermetically sealed containers with a desiccant.

This battery consists of long thin strips of silver foil previously chloridized on the surface and wound in a spiral with a strip of magnesium of similar dimensions. The two electrodes are separated by a strip of absorbent paper. The individual cells are housed in plastic containers which are

open on the sides or ends to admit water when the battery is to be activated.

The working voltage is about 1.5 volts under average load and the output is about 18 watt-hours per pound under heavy loads, or twice this value for light loads. It is made in a wide variety of sizes and voltages.

Another form of silver chloride-zinc cell long has been on the market for medical uses and as a source of electric potential. It is made in the form of a dry cell having an electromotive force of about 1.0 volt. The resistance of the cell is high and it is limited, therefore, in use to light current drains.

Low Temperature Dry Cells. Several types of low temperature dry cells have been produced to furnish acceptable electrical output at temperatures of −30 degrees centigrade and below. In appearance and method of construction they resemble ordinary cells and they have the same electromotive force. They differ from the ordinary cells, however, in the electrolyte.

(*a*). Methylamine Hydrochloride Cells. Unpublished experiments by D. N. Craig and J. P. Schrodt at the National Bureau of Standards had shown that several of the amine hydrochlorides have possibilities as substitutes for ammonium chloride in dry cells for low temperature operation. Further studies[22] showed that of the various methyl and ethyl amines, the monomethylamine hydrochloride gave the best performance. A solution of 47 per cent of this amine with 3 per cent zinc chloride freezes at −45 degrees centigrade. The shelf life and electrical output can be improved, however, by the addition of about 15 per cent

CURVE NO.	CHARGE OR DISCHARGE	CURRENT RATE	MATERIAL	THEORETICAL CAPACITY	OUTPUT % OF THEORY	REMARKS
		MA		AMP-HR		
1	DISCHARGE	50	Ag_2O	0.0960	94	PASTED
2	CHARGE	50				FORMED
3	DISCHARGE	50	Ag_2O_2	0.1935	81	
4	CHARGE	25			—	FORMED
5	DISCHARGE	50	Ag_2O_2	0.1898	87	
6	CHARGE	12.5			—	FORMED
7	DISCHARGE	50	Ag_2O_2	0.1865	94	
8	CHARGE	4.2			—	FORMED
9	DISCHARGE	50	Ag_2O_2	0.1817	96	
10	CHARGE	50			—	FORMED
11	DISCHARGE	50	Ag_2O_2	0.1800	78	
12	CHARGE	50	—	—	—	BARE PT

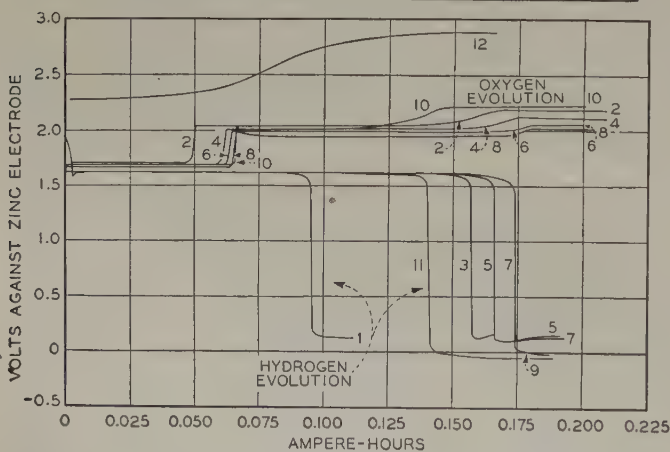


Figure 7. Electrode characteristics of silver oxides

The output of the silver peroxide, curves 3, 5, 7, 9, and 11, materially exceeds that of the ordinary silver oxide, curve 1, but the rate of charge of the former has a material effect on the efficiency

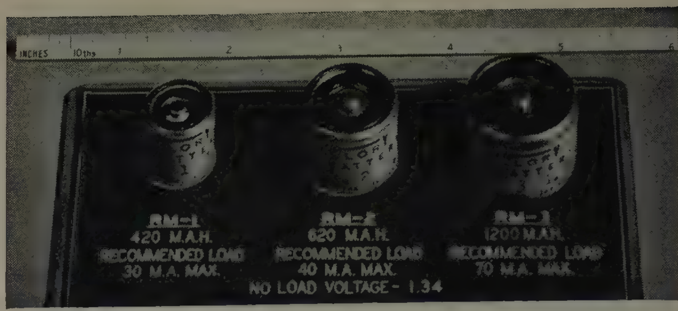


Figure 8. Three sizes of mercury oxide dry cells, commonly known as RM cells

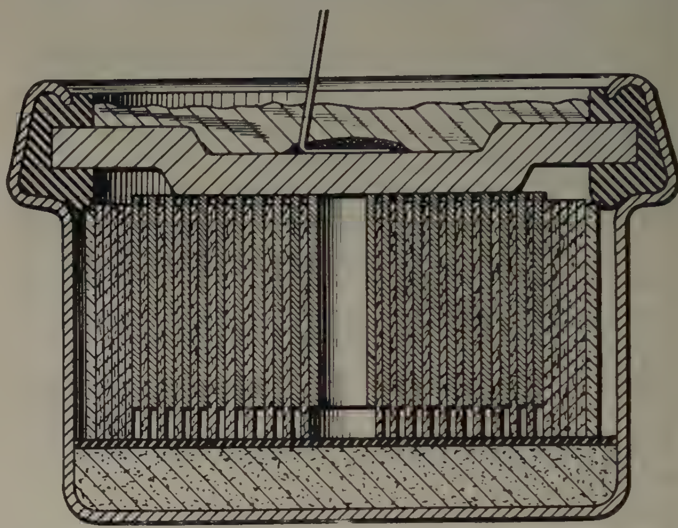


Figure 9. Enlarged cross section of an RM cell (mercury oxide dry cell)

The depolarizer, mercuric oxide, is at the bottom, covered by a separator; above it is the coiled zinc electrode in contact with the top closure. The outer case is steel. Unlike the ordinary dry cell, the central top contact is the negative pole

of ammonium chloride which appears to be necessary to stabilize the cells.

Other changes in constructing the cells were made to improve the electrical output. As additions to or substitutes for the usual starch-flour pastes, polyvinyl alcohol, methyl cellulose, or a salt of carboxy methyl cellulose were tried. These suffer, however, because of the gradual extraction of water from the separator wall.

The output of these cells at −30 degrees centigrade ranged from 10 to 20 per cent of the output of the usual (sal ammoniac) type at normal temperatures.

(*b*). Calcium Chloride Cells. Various combinations of calcium chloride and zinc chloride[22] led to varied results. When the mole strength of the zinc chloride was equal to or greater than that of the calcium chloride, cells of very constant voltage were obtained, but the output was small. The addition of a small percentage of sal ammoniac improved the output, but the constancy of voltage over long periods of time was then no better than for ordinary cells. The formula is critical. Best results were obtained with about equal mole strength of the salts on an anhydrous basis dissolved in a nine per cent solution of ammonium chloride. At a moderate drain, *D*-size cells discharging continuously

through 16 ohms at -30 degrees centigrade gave 833 minutes of service to 0.75 volt per cell.

(*c*). Lithium Chloride Cells. Wilke[23] produced a low temperature dry cell giving good results at -30 degrees and -40 degrees centigrade by the addition of lithium chloride to a sal ammoniac electrolyte. The solution used contained 10 per cent $ZnCl_2$, 15 per cent LiCl, 8 per cent NH_4Cl, and 65 per cent water. These cells have a flash current of 1.4 amperes at -40 degrees centigrade. On heavy drains (up to 10 hours duration at $+21$ degrees centigrade) they can give at -40 degrees centigrade about 10 per cent of normal capacity; on light drains about 20 per cent.

Mercury Oxide Cells. Dry cells of the alkaline type[24] are entirely different in materials and construction from dry cells most familiar to the public. The mercury-oxide cell developed during the war and used extensively in the walkie-talkies is a rugged steel-encased cell with alkaline electrolyte that has a relatively large electrical output for the space that it occupies. It is sometimes known as the *RM* cell. Several sizes are shown in Figure 8.

The cathode is mercuric oxide mixed with about 10 per cent graphite compressed into a pellet which lies in the bottom of the outer steel container. Above this is a barrier layer of porous electrolytically conducting material, serving as a separator between the cathode and anode. The latter is a coil of zinc in the form of a narrow strip about two mils thick and corrugated to increase its surface. It is rolled with a strip of paper into a short compact cylinder and amalgamated before being placed in the cell (Figure 9). The electrolyte is a solution of potassium hydroxide to which an addition of zinc oxide is made to reduce local action. The cell is sealed with a rubber or neoprene grommet.

The chemical reaction which occurs on discharge is said to be

$$Zn + KOH + HgO \rightleftarrows KHZnO_2 + Hg \qquad (8)$$

The electromotive force is about 1.3 volts per cell. In the small sizes now made it has an average output of about 0.08 watt-hour per gram at a working voltage of 1.25 volts per cell.

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Temperature Measured by Sound

How sound waves are used to measure upper atmosphere temperatures was described by Doctor E. F. Cox, Naval Ordnance Laboratory, Washington, D. C., at a joint meeting of the American Physical Society and the Institute of Aeronautical Sciences at Columbia University, New York, N. Y. Around a source of loud noise, such as the explosion of an ammunition dump, there are alternate rings of noise and silence. No noise can be heard at one place and a few miles away windows may be shattered by sound waves. This condition is caused by layers of hot air in the upper atmosphere which serve as reflectors, according to Doctor Cox.

The temperature of the first layer of air above the earth, extending 8 to 20 miles, averages about minus 75 degrees Fahrenheit. The next, containing a high proportion of ozone which absorbs ultraviolet rays from sunlight and gets heated in this manner, averages about plus 100 degrees Beyond this is another layer of colder air, and still higher the temperature again rises. Because sound waves are reflected back to earth by the hot layers of the upper atmosphere, measurements of sounds received at great distances from explosions can be used to calculate temperatures of the earth's outer air layers. This research is important, especially in problems of supersonic flight.

Observations made by the laboratory's scientists in connection with the demolition of German fortifications at Heligoland in April 1947, where 5,000 tons of TNT were exploded, showed that subsonic waves carried to Gorizia, Italy, 620 miles away. Temperature values calculated from these records show an ozonosphere peak of 70 degrees Fahrenheit at 35 miles altitude, a dip to minus 150 degrees at 45 miles, then a rise to plus 260 degrees at 100 miles.

Electric Drives With Fluid Couplings

FRED W. ATZ

The combination of a standard general purpose motor with a fluid coupling in a compact integral unit has produced an efficient device which is simple in operation, principle, and design.

HYDRAULIC DRIVES and couplings are classified into two general groups, constant and variable speed. These couplings also are known as fluid couplings, fluid drives, hydraulic drives, and hydraulic clutches. Combining the fluid coupling with a standard general purpose motor becomes what is known as the Electrofluid Drive.

There are many advantages inherent in this type of unit. The principal advantages are

1. To eliminate shocks, impacts, and torsional vibration.
2. To insure continuous smooth operation.
3. To maintain full torque at all output speeds.
4. To permit the use of a motor closely rated to the developed load to be driven.
5. To prevent stalling of the motor.
6. To eliminate shear pins and other similar protective devices.
7. To permit the use of a standard motor (a-c or d-c), eliminating the use of high torque, and high slip motors.

The application of the Electrofluid Drive is widespread in the industry in general, although its use has been limited. It has been applied successfully to numerous types of materials handling equipment and, because of its characteristics, lends itself to numerous applications in this particular field, such as belt conveyers, overhead cranes, skip hoists, and foundry mold conveyors.

CONSTRUCTION OF THE ELECTROFLUID DRIVE

The coupling is made of two main parts—runner (driven or load end) and impeller (driver or motor end). All couplings are of the double circuit type (two runners and two impellers) except the one, and $1^1/_2$-horsepower sizes which are of the single-circuit type. No metallic connection exists between the runners and impellers. In the double circuit units, the two impellers mechanically are connected to function as a unit; likewise, the two runners are connected positively to function as a unit. The coupling is filled with a light mineral oil of steam-turbine quality. When the motor drives the impeller, its multiple blades cause oil to flow against the multiple blades of the runner, through the runner buckets, and back to the impeller, thereby rotating the runner and transmitting power entirely by the mass and velocity of oil moving from the impeller to the runner.

Primarily a constant speed unit, it is designed for 1,800 rpm synchronous speed, 1,730 rpm full load speed. However, it also can be used on 25- and 50-cycle alternating current, having full load input speeds of about 1,450 rpm. At these speeds, the coupling operates at reduced rating, and in some instances oversize couplings must be used.

ACCELERATION

Acceleration, which is always of a smooth nature, depends on the inertia of the driven load—the greater the inertia, the longer the time of acceleration. The initial acceleration is more prolonged with the Electrofluid Drive than when the connection between motor and driven equipment is solid or of a positive nature. But, the current peaks are lower during the period of acceleration and maximum load conditions when the flywheel effect gives up its energy.

Considerable operating improvement can be expected with the use of a fluid coupling because of the speed characteristics (torque increases as the square of speed). The speed during the acceleration period develops torque as the speed increases, placing the entire drive in tension before rotation begins, which eliminates all shocks and impacts. During the running period, all load fluctuations are smoothed out in the cushion-like action of the coupling.

The characteristics of the Electrofluid Drive are such that the horsepower transmitted varies in proportion to the cube of the speed. Torque varies as the square of the speed and to the fifth power of the diameter. Motor torque varies as the square of the voltage.

The motor and coupling are mounted as an integral unit, thus eliminating the base plate and assuring accurate enduring alignment plus compactness and economy.

When used with a mechanical variable speed device, the effect is similar to that obtained from a variable speed hydraulic coupling. However, the speed is more positive, regulation is infinite, and the over-all efficiency is higher.

Large size fluid couplings adapt themselves more readily as independently mounted units, rather than integrally mounted. This method of design usually applies to 25-horsepower models and larger.

It is adapted to a-c as well as d-c shunt-wound motors, preferably 1,750 rpm, which have characteristics similar to the standard general purpose squirrel cage motor.

Although the drive is strictly of a constant speed nature, it can be used where the source is variable such as slip ring a-c motors or adjustable speed d-c motors with a ratio of 2 to 1 (1,800 to 900 rpm). Because of the torque–speed characteristics of the fluid coupling, a coupling having the torque rating at the lower speed must be used to provide sufficient torque at the lower speeds.

Essential substance of a conference paper, "Electric Drives With Fluid Couplings for Material Handling Equipments," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948.

Fred W. Atz is an electrical engineer with the Link-Belt Company, Philadelphia, Pa.

The fluid coupling changes the characteristics of the various motors. The standard squirrel cage type usually provides low starting torque with high pull-out torque. Where the starting torque usually is 160 per cent and the pull-out torque in excess of 200 per cent, the characteristics of coupling will make use of the motor torque up to maximum in starting the driven equipment. Thus, when using the combined unit, motor and fluid coupling, the motor characteristics of a standard squirrel cage motor changes to the extent of becoming a high-starting-torque low-starting-current motor. This combination can be substituted very readily for a high-torque high-slip motor, where high inertia loads are encountered or where frequent heavy loads are ironed out by means of flywheels. In this instance, the coupling, rather than the motor, provides the necessary slip.

The high-torque high-slip motor, when used with a fluid coupling, again changes its characteristics. The high starting torque at zero speed becomes useless, and the maximum torque becomes a lower value than when using a standard squirrel cage motor. The lower stalled torque value of the coupling results from the rapidly decreasing speed of the motor and its influence on the coupling which decreases in torque as the square of the speed. The fluid coupling, therefore, changes the characteristics of a high-torque high-slip motor to a low-torque high-slip low-starting-current motor. When the fluid coupling is used with this type of motor, the driven equipment can be designed for a lower factor of safety, because under stalled conditions the maximum torque imparted to the driven equipment is considerably lower than that of a standard squirrel cage motor. When regulation is required, such as the bridge traverse of a crane, considerable improvement can be secured over the conventional method of using a wound-rotor slip-ring a-c motor or a compound- or series-wound d-c motor, (regulation in the ratio of 2 to 1) by using a high-torque high-slip motor or a shunt-wound d-c motor. The fluid coupling, when used for regulation, must be selected on the basis of developing sufficient torque on the lower speeds as in the case where the highest speed is 1,800 rpm, no load, the torque should be selected as of 900 rpm.

VERTICAL OPERATION

The integral unit can be used for vertical operation. It will support its own weight including the rotor and coupling. Any additional downward thrust must be supported independently.

PROTECTION

Fluid coupling used in combination with an electric motor does away with shear pin protection which, at its best, is erratic and permits abuses in using substitutes for the shear pins, usually resulting disastrously. Protection usually is in the form of thermal overload relays, but also can be provided to trip on definite values where such protection is deemed vital to the protection of the machinery. The starting and protective equipment is standard, being of the across-the-line type of magnetic switch providing overload and undervoltage protection. It is the simplest form of equipment that can be used for remote control. The preset type of overload protection where the maximum torque, such as 150–200 or 250 per cent, to be transmitted can be predetermined, is accomplished by means of a preset instantaneous trip overload relay. This relay is out of circuit during the acceleration period during which time the thermal relay provides the protection. Where thermal elements provide the protection, overload peaks of short duration may occur. The motor through the fluid coupling absorbs these peaks until operation returns to normal.

PLUGGING FOR QUICK REVERSALS AND STOPPING

The motor can be reversed from full speed forward to full speed reverse, by the mere pressing of the respective buttons. The action is such as to apply maximum reverse

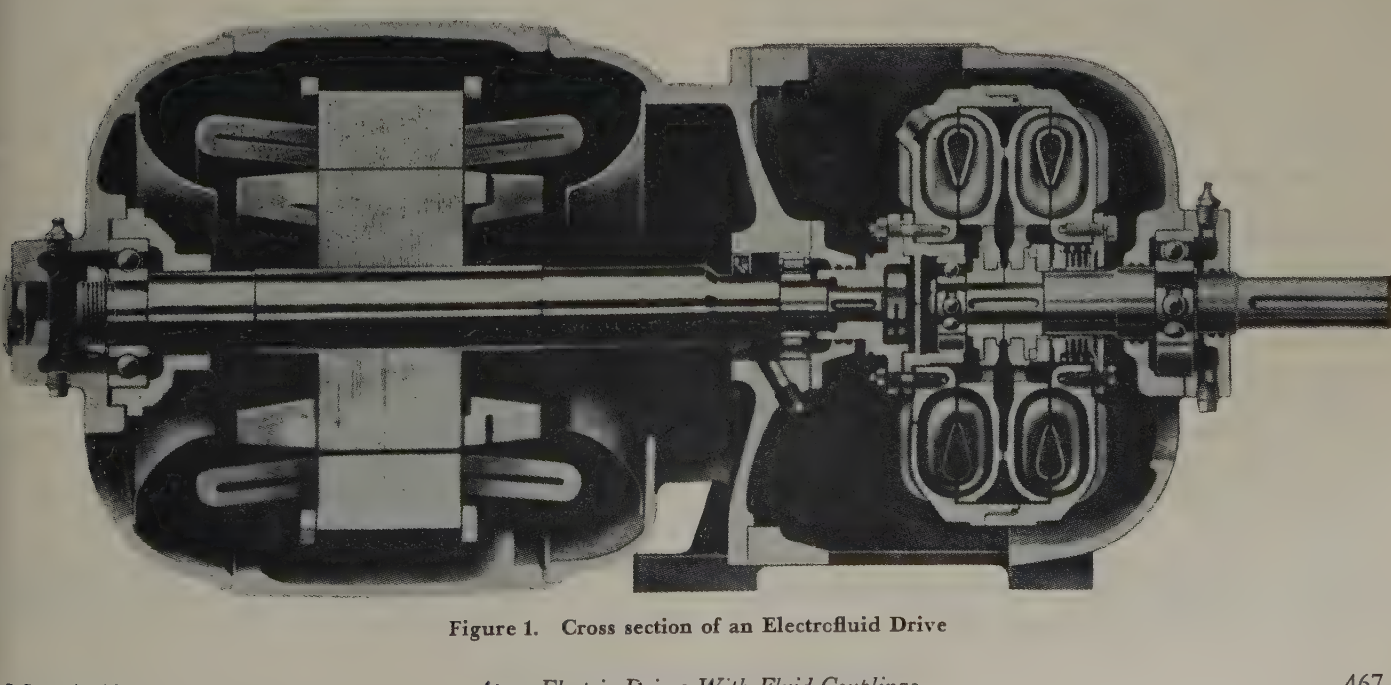

Figure 1. Cross section of an Electrofluid Drive

torque to the fluid coupling until the driven equipment actually rotates in the reverse direction. Quick accurate stopping can be effected by means of a plugging switch mounted on the driven shaft. This switch works on the centrifugal principle, throwing reverse current into the motor until the driven equipment stops. Just before the driven equipment stops, the plugging switch opens the entire motor circuit. At this point, a solenoid brake can be applied, should it be necessary to hold the load. By the use of this method, the Electrofluid Drive provides smooth deceleration and final stopping both by the quick stopping and the reversal method.

Maintenance is very low, the main item being an occasional inspection of the oil level to insure maximum efficiency and protection. The Electrofluid Drive permits the motor to utilize its maximum torque. Therefore, in most instances, regardless of the inertia, motors can be selected for the running load to develop maximum power factor.

The initial start of the motor is so rapid as to nullify the current peak as the momentary locked rotor condition is negligible. The motor accelerates rapidly up to approximately 70 per cent of full load speed before it exerts sufficient torque to accelerate the driven machine. At this speed, the current approximates three times full load current as compared with the usual starting peaks of six times full load running current.

Industrial Radioactivity Applications

An interesting article on industrial applications of radioactivity by M. Blau and J. R. Carlin appears in the April 1948 issue of *Electronics*. The authors point out that prewar uses for radioactive substances now have become economically attractive to many industries. A number of more recent applications of radioactivity in industry also are discussed.

Air loses its insulating properties and becomes conducting near sources of alpha particles. This ionizing power of alpha particles makes possible the dissipation of static electricity in nearby objects. The quantity of static electricity which can be eliminated within a certain time depends only on the alpha radiation intensity present.

The ionization power of radiation is utilized in a device known as a radioactive resistor which consists of a chamber in which one electrode is covered with a radioactive alpha-particle emitting substance and the other is connected to an electrometer or amplifier. As the voltage between the electrodes is increased, the ionization current will increase correspondingly until saturation is reached when all of the ions are being drawn to the electrode upon formation. If voltage is increased further, ionization by collision occurs and the current increases as in an avalanche. The first part of the ionization current–volts-per-centimeter curve is linear and is called the ohmic region. This region makes possible the construction of resistors with complete absence of polarization and temperature deficiencies. If the chamber is not hermetically sealed, outside pressure and temperature may influence ionization current. However, these influences are small, completely regular, simple to compute, and easily compensated for. Radioactive resistors have been used as leakage resistors of electrometers in radioactive laboratories. They also are useful in electronic circuits requiring high values of grid resistance. The higher the resistance value, the less radioactive material is needed. This type of resistor also can be used for measuring high voltages. By varying the quantity of emitted radiation or distance between electrodes, a wide range of voltages can be covered.

Light sources of various colors requiring no battery or power line connection can be produced by bombardment of fluorescent compounds with radioactive radiation. A radioactive light standard already has been developed, using radium as a constant radioactive power source.

Radioactive cathodes for vacuum tubes are suggested to serve in the place of heated cathodes, with such advantages as consistency of emission and uniformity of energy. If the beam of beta particles is concentrated by electrical or magnetic methods, high electric charges can be accumulated, or heat and light effects can be produced.

The penetrating properties of radioactive substances are utilized in a scanning device for testing homogeneity and thickness of films during production. The beta radiation penetrating a standard film is compared with that going through a sample film. The emergent radiation can be measured directly by the ionization effect produced in two identical ionization chambers, or indirectly by photoelectric tubes responding to light produced by fluorescent compounds.

The "radioactive integrator" for measuring irregular areas is a particularly interesting device. An electrode uniformly covered with polonium is positioned far enough below a wire mesh grid so that only the most perpendicular alpha radiation can ionize the space between the grid and another electrode mounted above the grid. The grid mesh is connected to the lower electrode. If a plane surface of unknown area is placed on the grid the ionization current will be reduced by an amount proportional to this area. This device can be used to measure porosity and open areas of mesh surfaces; to integrate the values of curves or charts that have been cut out along their peripheries; to determine the most efficient arrangement of patterns to be cut or stamped from metals or fabrics; and to measure areas of such things as precious metals, oils, furs, and leathers. If the radioactive plate is coated with a beta emitter the apparatus can be used for thickness or density measurements of plastics or organic materials, and for volume determination. For metallic materials the radioactive energizing material should be a gamma ray emitter.

Displacement detectors; based on the principle that when a radioactive material is coupled to the moving parts of a system, changes in position cause changes in ionization current or light effect that can be amplified to give a high degree of sensitivity and precision; also were cited.

The Separation of Isotopes

G. WESLEY DUNLAP
FELLOW AIEE

R. M. LICHTENSTEIN

Eight methods are available for separating isotopes or enriching the desired isotope content of a mixture. Each is based upon either a physical or chemical phenomenon dependent upon the mass weight rather than the charge on the nucleus. This is the sixth of a series of articles developed by the AIEE nucleonics committee; the entire series will be published in pamphlet form upon its completion.

THE STUDY of isotopes which has been of scientific interest for more than 30 years comes into sharp focus in the field of nucleonics. Because nuclear properties depend specifically on the isotopic forms of the elements, the separation of isotopes for study and use is of prime importance. This was in fact one of the major operations of the atomic bomb project, and the tremendous plants which were built for the separation of the uranium isotope $_{92}U^{235}$ are well known.

HISTORY OF SEPARATION METHODS

Until the discovery of isotopes[1] in 1911 by F. Soddy it was assumed that the atoms of a given element were identical in all respects. With the discovery of isotopes it was necessary to recognize that the atoms of such elements differed in atomic weight, but because it had proved to be impossible to separate the isotopes of the natural radioactive substances by chemical methods, it was concluded that the chemical properties of these isotopes were again identical, and that only those properties which depend directly on atomic weights could be expected to vary at all. These properties include rates of diffusion through porous media; the density of the gaseous, liquid, and solid states; and differences in radioactive properties. Accordingly, the first attempts to separate isotopes made use of physical methods of separation. There were the early attempts to show that isotopes could be separated by diffusions through porous media, conducted by F. W. Aston, and the development by Sir J. J. Thompson and subsequently by Aston of electromagnetic methods for the identification of stable isotopes by the separation of charged ions of the elements.

Sir J. J. Thompson developed methods for separating isotopes in very small amounts by the use of crossed electric and magnetic fields acting upon a beam of ions moving in a direction perpendicular to these fields. This method was developed further by F. W. Aston and subsequent workers using mass spectrographs or mass spectrometers, in which the ions first are accelerated by means of the electric field and subsequently pass through a magnetic field to deflect the ions. The ions of different masses are deflected in amounts depending on the ratio of charge to mass, and hence a separation of ions is secured. During the early development of the separation of isotopes, only ultramicroscopic amounts of isotopes were separated by these methods.

Immediately after the discovery of the electromagnetic method for the detection of isotopes, the diffusion of gases through porous membranes was investigated by F. W. Aston, G. Hevesy, and W. D. Harkins, and in this way small changes in the relative concentrations of isotopes were accomplished. Considerably later Gustav Hertz developed the cascade diffusion method and made it possible to increase the small effects due to diffusion by feeding the separated products from one diffusion unit to other units in a series and thus increase the fractionation produced by the over-all apparatus. This method was used to separate small amounts of the isotopes of common elements during the 1930's.

Early in the development of the subject, F. A. Lindemann pointed out that differences in the vapor pressures of the lead isotopes would be expected if certain theoretical predictions were true. However experiments made at that time showed no observable differences, and it was assumed that differences did not exist. The immediate result of these studies was to discourage all attempts to discover any differences in chemical properties of the isotopes of the elements or their compounds. As a result, chemical methods for separating isotopes, that is, methods based on differences in vapor pressures and differences in the equilibrium constants* of chemical reactions, were not observed for a very considerable number of years. Had this historical prejudice against differences in chemical properties not

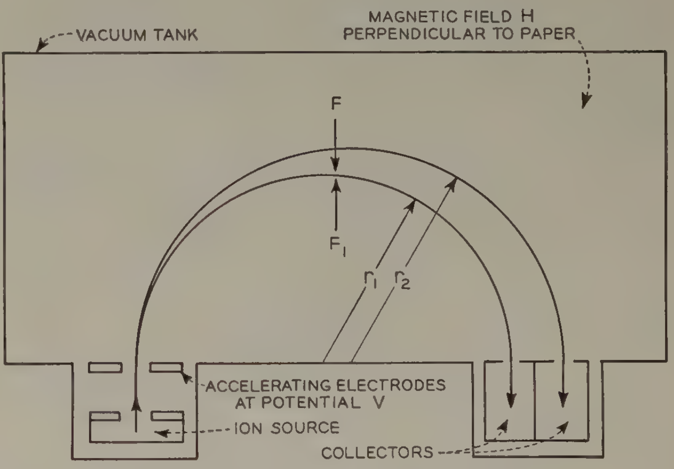

Figure 1. The electromagnetic process

G. Wesley Dunlap is an assistant division engineer in the engineering and consulting laboratory of the General Electric Company, Schenectady, N. Y. R. M. Lichtenstein, is also with the general engineering and consulting laboratory, General Electric Company.

* Equilibrium constant determines the amount of each substance produced by an exchange reaction when equilibrium is reached. This is discussed in more detail in another section.

developed it seems probable that good methods for the separation of certain isotopes might have been developed much sooner than they were.

Thus, differences exist in the vapor pressures of the waters depending upon their hydrogen or oxygen isotopic composition which are of sufficient magnitude to change the density of water by easily measurable amounts. It is in fact difficult to purify water for the purposes of isotopic analysis by density methods without changing the relative abundances of both the hydrogen and oxygen isotopes by sufficient amounts to invalidate the results. It was with the recognition of these facts that some chemical separation methods were developed during the 1930's.

The discovery of heavy hydrogen ($_1H^2$) gave an example of isotopes of one element which were so markedly different in chemical properties that their differences could not be overlooked, and this led quite naturally to the investigation of the differences in chemical properties of other isotopic substances. The result of all of these investigations showed that quite generally in the case of the lighter elements, differences existed in the vapor pressures of isotopic substances of the order of magnitude of a per cent or less. This difference is so small that it is very difficult in most instances to make use of distillation as a method of separation. However, differences in the equilibrium constants of exchange reactions are somewhat larger, amounting to a few per cent, and these small differences are sufficiently large to make possible the separation of isotopes.

In 1938 K. Clusius and G. Dickel discovered the thermal diffusion column method for the separation of isotopes when isotopes of oxygen, neon, chlorine, and krypton were successfully separated. It had been known for many years as a result of the work of S. Chapman and M. H. C. Knudson that the thermal diffusion coefficient of gases depends upon the molecular weight of the molecule being diffused. Thus if a gas is placed between surfaces which are at different temperatures, the lighter molecules preferentially concentrate at the hot surface and the heavier ones at the cold surface.

During World War II, A. K. Brewer and S. L. Madorsky discovered that the ions of the isotopes of potassium in water solution had different mobilities. The difference in mobility was not inversely proportional to the square root of the atomic weights, but considerably less than this, as might be expected from considerable hydration of the ions. Though appreciable separation of the isotopes was secured, no large separation was affected by this method, and though the method may have some promise, very considerable development would be required in order to decide this point.

It was recognized early that the centrifuge should produce a difference in concentration of isotopes between the periphery of the centrifuge and points nearer to its axis. R. S. Mulliken particularly developed the theory of this process. During the 1930's J. W. Beams developed centrifuge methods for changing the relative abundances of isotopes by small amounts.

Although all of these methods are not feasible from economic or practical points of view, it is advisable to understand the scientific principles upon which each process is based. The eight basic types of processes are

1. Electromagnetic.
2. Gaseous diffusion.
3. Thermal diffusion.
4. Ion mobility.
5. Centrifuge.
6. Fractional distillation.
7. Chemical exchange.
8. Electrolysis.

ELECTROMAGNETIC PROCESS

As indicated previously, this method is based on the principle of the mass spectrograph which may be explained by reference to Figure 1.

Neutral gas molecules are ionized in the ion source by bombardment with electrons. The ionized particles then are accelerated and collimated into a beam by the system of electrodes shown. This beam is projected into a magnetic field (perpendicular to the paper in Figure 1) where the moving ions are acted upon by a force F. As is well known, the force on a particle of charge e moving with a velocity v in a magnetic field of strength H is exerted at right angles to both the field and the direction of motion and is given by the equation

$$F = Hev \qquad (1)$$

As the ions are forced into a circular path the force F must be balanced by the centrifugal force F_1. Because

$$F_1 = \frac{mv^2}{r} \qquad (2)$$

where m is the mass, v the velocity, and r the radius, the relation governing the ion path is

$$Hev = \frac{mv^2}{r} \qquad (3)$$

The velocity of the ions may be determined from the relation

$$Ve = \frac{1}{2}mv^2 \qquad (4)$$

where V is the accelerating voltage and an equation relating

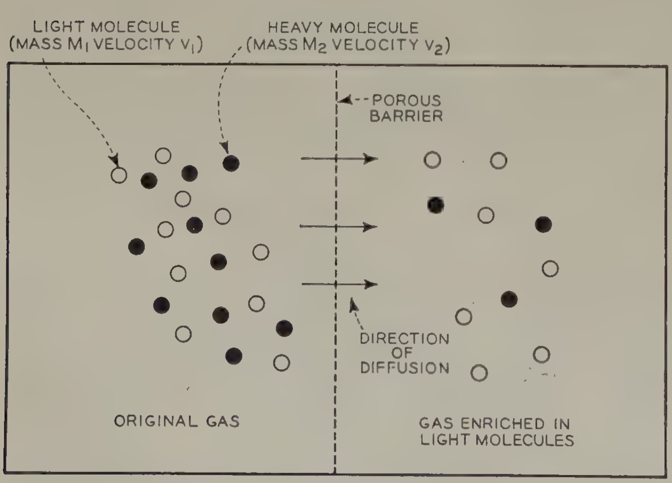

Figure 2. Gaseous diffusion process

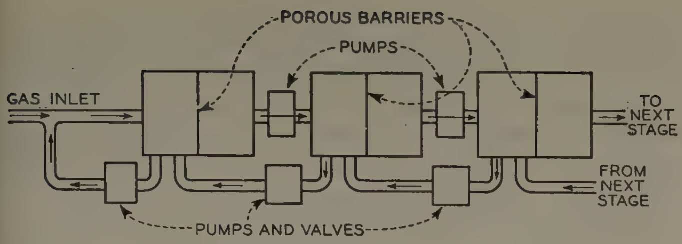

Figure 3. Gaseous diffusion process with cascaded stages

mass with the radius of curvature may be derived as follows:

$$\frac{m}{e}=\frac{r^2H^2}{2V} \tag{5}$$

or, if m is in atomic mass units, e the number of electron charges, r in centimeters, H in gauss, and V in electron volts this becomes

$$\frac{m}{e}=4.82\times10^{-5}\left(\frac{r^2H^2}{V}\right) \tag{6}$$

From this it is seen that the radius of the ion path will depend on the mass of the ion and collectors may be positioned to collect ions of specific masses.

Prior to World War II, little consideration had been given to this method as a means of separating isotopes in any quantity. However, the importance of concentrating ${}_{92}U^{235}$ led to intensive effort which resulted in the development of an electromagnetic separator called the calutron (after California University cyclotron) to distinguish it from its smaller predecessor, the mass spectrograph.

This method is capable of high resolution, or, in other words, a large fractionation of the isotopes is obtained in a single operation. However, it is limited as to the quantity of material that can be handled in a single run. A compromise may be effected between resolution and yield, but for any sizeable production a number of units operating in parallel must be employed.

Large scale separation of the uranium isotopes was accomplished by this method and since the war isotopes of other elements have been separated in useful amounts.

GASEOUS DIFFUSION PROCESS

The principle of separation of isotopes by diffusion of a gas through a porous barrier was demonstrated soon after the discovery of isotopes. Actually the principle had been demonstrated even earlier in experiments in which mixtures of gases of different atomic weights partially were separated by diffusion.

The phenomenon depends on the fact that in a gas mixture containing molecules of different masses, the lighter molecules will diffuse through a porous wall or barrier more readily than the heavier ones. This is explained as follows. Because the average kinetic energy of the molecules in a gas is a constant it follows that the average velocity of lighter molecules is greater than the average velocity of heavier molecules. Thus in a mixture of two kinds of molecules having masses m_1 and m_2, their average velocities may be obtained by equating the kinetic energies

$$\frac{1}{2}m_1v_1^2=\frac{1}{2}m_2v_2^2 \tag{7}$$

whence

$$\frac{v_1}{v_2}=\sqrt{\frac{m_2}{m_1}} \tag{8}$$

If then a mixture of light and heavy molecules of gas as in Figure 2 is allowed to diffuse through a porous wall in which the holes are the right size to pass one molecule at a time, the lighter molecules will get through more quickly and, in a given short time, in greater numbers by a factor of v_1/v_2. Thus an enrichment of the percentage of lighter molecules will be obtained and the amount of enrichment may be described by a separation factor which is $\sqrt{m_2/m_1}$.

This condition, of course, will hold only so long as the relative concentrations of light and heavy molecules in the original mixture are not appreciably changed. In practice of course the original gas would be replenished continuously while the enriched component continuously would be removed.

Actually this theoretical separation never is realized completely in practice because of back diffusion from the enriched side and because irregularities in barriers permit some mass flow of the gas instead of true diffusion.

As the differences in mass of the isotopes of an element are only a matter of an extra neutron or so, it is apparent that only a very small separation can be expected in a single stage of this method. For example, to separate ${}_{92}U^{235}$ from ${}_{92}U^{238}$ a gaseous compound, uranium hexafluoride, is used. The respective molecular weights are then 349 and 352 so the separation factor $\sqrt{352/349}$ is 1.0043. It is therefore necessary to cascade a number of individual stages (as shown in Figure 3) to obtain significant over-all separation. In the separation of uranium isotopes, thousands of stages are required to achieve the desired result.

Here again a compromise must be made between the amount of material handled and the enrichment per operation. This will be discussed in a later article. However, it should be pointed out that this process is capable of handling very large quantities of material and is particularly suitable for large scale concentration of isotopes as in the tremendous uranium plant at Oak Ridge, Tenn.

THERMAL DIFFUSION PROCESS

The exact theory of this process is very complicated for gases and even worse for liquids. For the purpose of this

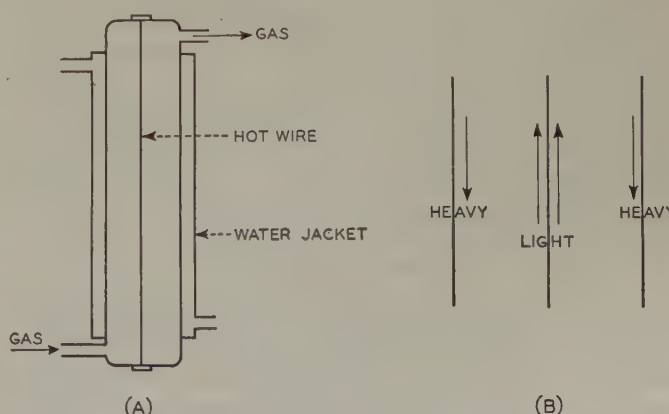

Figure 4. Thermal diffusion process

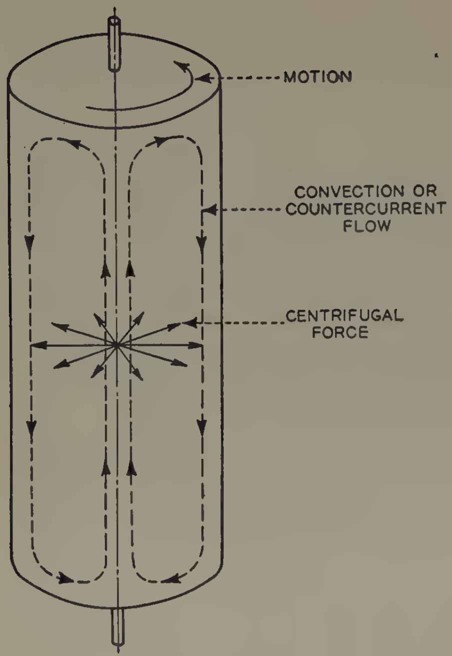

Figure 5. Centrifuge

discussion it is perhaps sufficient to give only a simplified explanation.

As indicated under the "Gaseous Diffusion" section, the rates of diffusion of gases of different molecular weights differ to an extent which is a function of their masses. This phenomenon, combined with the fact that the transfer of momentum in a collision between molecules depends on both the weights of the molecules and on the force between them, means that if a temperature gradient exists, there may be a tendency for one type of molecule to concentrate near the hotter surface while another concentrates near the colder surface. K. Clusius and G. Dickel provided these surfaces in a column (Figure 4*A*) with a heated wire placed concentrically in a cylinder with a cooled wall. In this apparatus, thermal diffusion causes a movement of the lighter isotopes toward the hot wire and a movement of the heavier ones toward the cold wall. If this were the only effect, the realizable separation would be very small. However, in a long column a cascading effect occurs because of ordinary convection. The light isotope moves upward along the hot wire (Figure 4*B*) and is concentrated near the top, while the heavy one moves downward along the cold wall and is concentrated near the bottom. This cascading effect will be discussed in another article of this series.

This method is particularly suitable for laboratory operation as it may be simple and automatic. In some instances practically complete separation may be achieved. On the other hand equipment can be designed to handle large scale operations as in the thermal diffusion plant at Oak Ridge. In the latter instance large amounts of power are required to maintain the required temperature gradients.

ION MOBILITY METHOD

This effect which was demonstrated during the war by A. K. Brewer and S. L. Madorsky at the National Bureau of Standards, Washington, D. C., has not been developed for any extensive use. It depends on a difference of mobility of ions under the influence of an electric field in an electrolytic solution. The difference is a function of the molecular weights but turns out to be rather less than inversely proportional to the square root of the masses. As this difference is very small, it easily may be obscured by other effects, and the method probably is limited as to application. So far only the separation of potassium isotopes has been reported.

CENTRIFUGE

As indicated previously, it was proposed quite early that atoms falling in a gravitational field might be restricted by intermolecular forces in such a way that there would be a tendency toward the separation of the lighter from the heavier ones. This effect was demonstrated to exist particularly by J. W. Beams who used a high speed centrifuge.

The centrifuge is shown diagrammatically in Figure 5. If a gas containing light and heavy isotopes is caused to spin at high speeds, the radial forces which are very high compared to gravity will cause an increase of concentration of the heavier ones near the periphery and an increase of the lighter isotope concentration near the axis of the chamber.

Although this effect depends on the difference between the masses rather than on their square root as with the diffusion methods, the separation is still small. However, advantage can be taken of the cascading effect of countercurrent flow as with the thermal diffusion process. This was suggested by H. C. Urey and centrifuges of this sort have been operated successfully. A pilot plant for the separation of uranium isotopes by this method was built and operated, but the method has not been developed for large scale operations.

FRACTIONAL DISTILLATION, CHEMICAL EXCHANGE, ELECTROLYSIS

Like the centrifuge just discussed, these methods depend on thermodynamic principles and the separation process may be described for the general case as follows. One starts out with a homogeneous mixture of isotopes, feeds it into a properly designed apparatus, and waits for the establishment of thermodynamic equilibrium, that is, one waits until the temperature is the same all over the apparatus and until all convection currents have subsided. (Of course, the apparatus must be designed and operated in such a way that thermodynamic equilibrium may be attained.) Although the original mixture of isotopes was homogeneous throughout, one will find that, after thermodynamic equilibrium has been established, the lighter isotope is enriched in one portion of the apparatus, whereas the heavier isotope is enriched in another portion. In practice one deliberately may set up temperature gradients and allow convection currents to flow, to increase the yield of the process. However, partial separation of the isotopes will take place even in the case of thermodynamic equilibrium.

These three separation processes are based on the fact that there are actually chemical differences between the various isotopes of one and the same element. At first sight this sounds strange, as one often is inclined to define isotopes as atoms which, though differing in mass, have the same chemical properties. Yet the very fact that the masses of the various isotopes of one element are different, produces a difference in chemical behavior.

To see why this is so let us consider the following two exchange reactions between hydrogen ${}_1H^1$, deuterium ${}_1H^2$ (or D), and iodine ${}_{53}I^{127}$.

$H_2+D_2 \rightarrow 2HD$
$H_2+2DI \rightarrow 2HI+D_2$

According to the mass action law of chemistry, the partial pressures P_{H_2}, P_{D_2}, P_{HD}, P_{HI}, P_{DI} of the five gases hydrogen H_2, deuterium D_2, deuterium hydride HD, hydrogen iodide HI, and deuterium iodide DI obey the following two equations:

$$\frac{(P_{HD})^2}{(P_{H_2})(P_{D_2})}=K_1 \tag{9}$$

$$\frac{(P_{HI})^2(P_{D_2})}{(P_{DI})^2(P_{H_2})}=K_2 \tag{10}$$

where K_1 and K_2 (the equilibrium constants) depend only on the temperature and not on the partial pressures.

Suppose the hydrogen contains a small percentage of deuterium, let us compare the relative abundance of deuterium in hydrogen gas, that is, the number $\frac{P_{HD}+2P_{D_2}}{P_{HD}+2P_{H_2}}$ to the relative abundance of deuterium in the form of the iodide, that is, the number $\frac{P_{DI}}{P_{HI}}$. (The term "relative abundance" denotes the quotient: the amount of deuterium divided by the amount of hydrogen.) From equations 9 and 10 we find (for not too high an abundance of deuterium):

$$\frac{P_{DI}}{P_{HI}}=\frac{2}{\sqrt{K_1K_2}}\cdot\frac{P_{HD}+2P_{D_2}}{P_{HD}+2P_{H_2}} \tag{11}$$

If hydrogen and deuterium had identical chemical behavior, then K_1 would equal four, and K_2 would equal unity. And then according to equation 11

$$\frac{P_{DI}}{P_{HI}}=\frac{P_{HD}+2P_{D_2}}{P_{HD}+2P_{H_2}}$$

that is, the relative abundance of deuterium would be the same in the iodized form as in the noniodized form. Actually, at room temperature (25 degrees centigrade) we have

$K_1=3.27$
$K_2=1.16$

so that

$$\frac{P_{DI}}{P_{HI}}=1.025\times\frac{P_{HD}+2P_{D_2}}{P_{HD}+2P_{H_2}} \tag{12}$$

that is, the deuterium is enriched in the iodized form.

On lowering the temperature we find that both K_1 and K_2 become smaller; they even approach zero, as the temperature is lowered towards the absolute zero. Thus at lower temperatures deuterium becomes appreciably enriched in the iodized form. A separation procedure may be based on this reaction.

Why do the numbers K_1 and K_2 differ from the values four and one? There are mainly two reasons:

1. The $H_2+D_2 \rightarrow 2HD$ and $H_2+2DI \rightarrow 2HI+D_2$ reactions require energy. The first requires 157 calories per mole and the second requires 83 calories per mole. These reaction energies are only about 1/1,000 of those required for ordinary chemical reactions. However, they are significant.
2. Space has a certain difficulty to accommodate molecules, even if they are of negligible size. This is a typical quantum mechanical phenomenon.

In explanation of reason 1: the molecules H_2, D_2, and HD have the same electronic structure. As it is the electronic structure which determines chemical phenomena, it may seem strange that two HD molecules contain more energy than an H_2 and a D_2 molecule. This certainly would not be the case, if in a hydrogen molecule the nuclei would just sit quietly side by side at their proper distance, which is determined by the electronic structure. However, the nuclei do not sit quietly, but they perform their so-called "zero point vibration" that is, they oscillate by alternately coming closer to one another and receding again. The energy of this zero point vibration is equal to $h\nu/2$, where h is the Planck constant and ν is the frequency of the vibration. This frequency is given by the equation

$$\nu=\frac{1}{2\pi}\sqrt{\frac{k}{\mu}} \tag{13}$$

where k is the force constant (the force required to increase the internuclear distance by a unit amount) and μ is the so-called reduced mass, that is,

$$\mu=\frac{M_1M_2}{M_1+M_2} \tag{14}$$

where M_1 and M_2 are the masses of the two nuclei respectively. The force constant k is determined by the electronic structure of the molecule, and therefore is the same for an H_2, a D_2, and an HD molecule. If m stands for the mass of a proton, then the mass of a deuteron is roughly $2m$. Thus the reduced masses of an H_2, a D_2, and an HD molecule are

$$\left.\begin{array}{l} m\times\frac{1\times1}{1+1} \\ m\times\frac{2\times2}{2+2} \\ m\times\frac{1\times2}{1+2} \end{array}\right\} \tag{15}$$

respectively. The zero point energies of these three molecules are therefore

$$\left.\begin{array}{l} \frac{h}{4\pi}\sqrt{\frac{k}{m}}\times\sqrt{2} \\ \frac{h}{4\pi}\sqrt{\frac{k}{m}}\times\frac{1}{\sqrt{1}} \\ \frac{h}{4\pi}\sqrt{\frac{k}{m}}\times\sqrt{\frac{3}{2}} \end{array}\right\} \tag{16}$$

respectively. The zero point energy of two HD molecules is larger than the zero point energy of an H_2 and a D_2 molecule by the amount

$$\frac{h}{4\pi}\sqrt{\frac{k}{m}}\left[2\sqrt{\frac{3}{2}}-\sqrt{2}-1\right]=\frac{h}{4\pi}\sqrt{\frac{k}{m}}\times0.035 \tag{17}$$

which is a positive quantity. The value of $(1/2\pi)\sqrt{k/m}$ can be obtained from spectroscopic evidence to be equal to

9.357×10^{13} second^{-1}. With this value one finds that, per mole of reacting material, the reaction

$H_2 + D_2 \rightarrow 2HD$

requires 157 calories. Similarly one finds that the reaction

$H_2 + 2DI \rightarrow 2HI + D_2$

requires 83 calories.

At low enough temperatures the low energy side of any chemical reaction is favored over the high energy side. Thus the equilibrium of the last reaction will be shifted away from the $2HI + D_2$ side and towards the $H_2 + 2DI$ side, so that the deuterons will be enriched in the iodized form.

In explanation of reason 2: suppose an atomic particle of negligible dimensions is confined to move in a cubical enclosure of linear dimension Δx. If classical mechanics were to govern the behavior of atoms, then there would be no difficulty in doing this. However, quantum mechanics states that the particle has an uncertainty in momentum Δx, given by the Heisenberg uncertainty relation $\Delta p \times \Delta x \approx h$, where h is Planck's constant. Thus the particle will not just sit in its enclosure, but will race back and forth with an average momentum of $\Delta p = h/\Delta x$. The kinetic energy then will be

$$E = \frac{(\Delta p)^2}{2m} = \frac{h^2}{(\Delta x)^2 2m} \tag{18}$$

Thus the lighter the particle is the more energy is required to confine it to a narrow space. Or vice versa, space cannot accommodate light particles, unless sufficient energy is provided. This reluctance of space to accommodate atomic or molecular particles will be the more pronounced the lighter the particle is. It is beyond the scope of this article to discuss the numerical consequences of this phenomenon, as far as chemical equilibria are concerned. But it is plausible that chemical equilibria will be influenced by this effect. The mathematical techniques of statistical mechanics enable us to account exactly for the reluctance of space to accomodate light particles, and, as a matter of fact, calculate the way in which chemical equilibria will be affected by this phenomenon in accordance with observation.

The fact that there is a difference in the chemical behavior of the various isotopes of one element can be utilized for the separation by various chemical methods, for example, fractional distillation, chemical exchange reaction of the type

$H_2 + 2DI \rightarrow 2HI + D_2$

and electrolysis.

All three of these methods are used successfully to separate the hydrogen isotopes, that is, in the production of heavy hydrogen (deuterium) or heavy water, and the chemical exchange method has been applied in the separation of the isotopes of nitrogen, carbon, and sulphur.

The first two usually are carried out by means of columns where countercurrent flow is maintained with a downward flow of liquid and an upward flow of gas or vapor. Electrolysis on the other hand requires an electrolytic cell.

In practice a combination of electrolysis with one of the other methods may be utilized.

Further discussion of the problems involved in selecting a process to meet specific demands will be included in the subsequent article of this series.

REFERENCE

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Radar Studied for Weather Forecasting

Experiments with synthetic raindrops are helping Westinghouse research men to determine the effect of rain and snow on 1.25-centimeter (K-band) radar. Primary object is to determine the weather-forecasting possibilities of these ultrashort waves. Basis of the work is the assumption that if raindrops reflect or scatter K-band waves, a means may be at hand to spot storm or hurricane areas many miles away.

Artificial raindrops are made in a range of carefully calculated sizes of ceramic powder and carbon black to achieve the appropriate electrical characteristics. In the tests a "raindrop" is fastened to a background that absorbs nearly all of the radiation not striking it. Microwave energy transmitted by a horn-type antenna is directed toward the raindrop, and is reflected into a receiving antenna placed at various distances and angles from the target. Actual measurement of the amount of scattering from the raindrop is accomplished by means of a wave guide balancing circuit. First microwave energy is transmitted without the raindrop in the field, and the amount of scattered energy received is balanced with a lower level signal feeding from the transmitter into the balancing circuit. Then the target is placed in the field, causing a change in the received energy which unbalances the detecting circuits. The additional power needed to rebalance the circuit is a measure of the increase of scattered energy due to the introduction of the raindrop. Amplifiers build up the unbalanced output so that a null point can be read accurately on an indicating meter.

Chief aim is to verify two basic "guesses" for which there has been much fragmentary evidence. One is that scattering of microwave energy from raindrops is most intense at certain frequencies. The other is that these frequencies are a function of the diameter of the individual particles of rain. Sensitivity to extremely small amounts of energy is required. The equipment used must be capable of detecting and measuring changes as small as 10^{-14} watt.

An Improved Low-Voltage Air Circuit Breaker

LEON H. SPEROW
MEMBER AIEE

JOHN A. FAVRE

A NEW 225- and 600-ampere frame size air circuit breaker incorporating the recent war improvements is now available. The principal advantages offered in this design over older ones specifically are

1. An improved arc chute of reduced size.
2. Long-lived contacts with momentary ratings equal to interrupting ratings.
3. Flexible and rugged overcurrent devices capable of necessary precision timing for selective tripping systems, but equally suitable for simple overload protection.
4. A 30 per cent reduction in size.
5. Longer life and lower maintenance from improved design.

CONTACTS AND INTERRUPTER

Two or more contact fingers are used for each pole and are separated by perforated phospho asbestos arc barriers. This design makes it possible to split the arc and quench three or four small arcs in a smaller space than an equivalent single arc requires. The contacts are faced with a high conductivity arc-resistant material. Their efficiency is attested to by the fact that they have a momentary rating equal to their interrupting rating and that their resistance after arc interruptions of considerable magnitude shows little change.

The contacts have been designed to eliminate troublesome heavy braids. The front or movable contacts are hinged on a close fitting preloaded silver-plated pin, while the back or fixed contacts use a line contact pivot. The fixed contacts with their supports form a reverse loop which increases the contact pressure under the action of high current. This feature is of considerable value as it permits lighter contact pressure than is permissible without such a loop, which in turn reduces the wear on the contact and on the mechanism.

The interrupter and contact structure has been tested thoroughly over the entire range of currents to establish 600-volt a-c and 250-volt d-c interrupting ratings of 15,000 and 25,000 amperes for the 225- and 600-ampere frame sizes respectively.

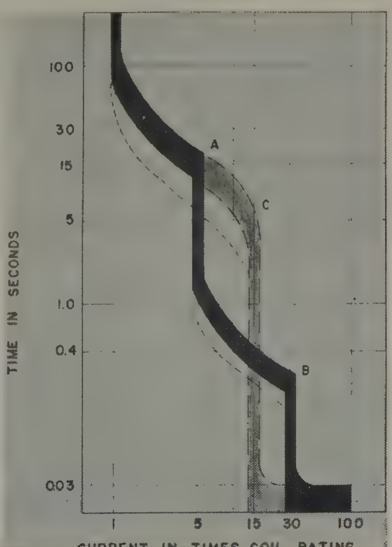

Figure 1. Typical time-current characteristic of the 2-armature 3-element overcurrent tripping device

OVERCURRENT TRIPPING

The familiar dual magnetic tripping devices relying on the adhesion of two mating disks in oil have served industry for many years. For most commercial applications they gave satisfactory service, but fundamental limitations became serious with the advent of selective tripping when more precise and reliable timing became a must.

In the new overcurrent tripping device one armature operates the instantaneous element and the positive-displacement long-time element using silicone oil. The other armature operates the mechanical escapement short-time element. The three elements of this overcurrent tripping device have been designed to be combined in any way desired. Standard combinations are

Instantaneous—high set, nonadjustable.
Instantaneous—low set, adjustable.
Long time and instantaneous.
Short time and instantaneous.
Long time, short time, and instantaneous.

A combined time-current characteristic of a device having all three elements is shown by the solid band in Figure 1, and for one having only long time and instantaneous by the shaded band. In the case of the solid band, the adjoining portions of the different characteristics are produced by separate armatures, thus the sharp intersections at *A* and *B*.

SUMMARY

This new development may be summarized by saying that industry is offered a new circuit breaker in which high inrush and momentary currents are handled easily, with an increased contact life. Accurate and proved timing elements have been provided giving a variety of desired time-current characteristics. A wider application on motor and other repetitive-duty high-inrush-current circuits is assured by longer contact and mechanism life and accurate delayed tripping obtained with the fluid displacement timing elements. Dependable selective operation can be obtained without the additional expense of current transformers and relays. Contacts and coils which will stand the high momentary currents, while tripping is delayed with an accurate mechanical timing device, make possible dependable selective operation, so unquestionably proved on the Navy's major ships.

Digest of paper 48-166, "An Improved Design of Low-Voltage Panel-Mounted Air Circuit Breaker," recommended by the AIEE committee on switchgear and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Leon H. Sperow and **John A. Favre** are both with the air circuit breaker division o the General Electric Company, Philadelphia, Pa.

Improving Electric Railway Fault Clearing Times

H. F. BROWN
FELLOW AIEE

H. A. TRAVERS
ASSOCIATE AIEE

C. A. WOODS, JR.
MEMBER AIEE

THE CIRCUIT BREAKERS designed in 1913 for sectionalizing the 11/22-kv 3-wire trolley and feeder circuits on the New Haven Railroad electrification had become inadequate by 1936 because of limited interrupting capacity to clear line faults fast enough to insure system stability and reliability. Although these never were designed to handle the entire fault interruption duty, space and weight limitations in the switching stations and supporting structures ruled out their replacement with modern circuit breakers of conventional design for faster fault clearing by line circuit breakers directly. The oil circuit breakers are known as "bridge-type" circuit breakers because of their location on the anchor bridges spanning the railroad tracks and catenary contact system. Figure 1, of a typical switching station, clearly indicates the space and weight limitations involved because of the location of the circuit breakers on the anchor bridges.

Delayed tripping of the bridge-type oil circuit breakers was accomplished by means of a "resistance-insertion" scheme of fault clearing. In this scheme "master" relays prevented tripping of trolley and feeder circuit breakers in case of a fault until resistances located at the power supply points were cut-in series with the lines. In this manner the fault currents interrupted by the circuit breakers were reduced to less than 3,000 amperes, rms, but the scheme required approximately 0.7 second of time to clear the faults. As most of the fault clearing time was consumed by the time delay resistance-insertion scheme, any appreciable reduction in this time required immediate tripping of the line circuit breakers with the resultant manifold increase in interrupting duty.

The application of modern interrupters to the original circuit breakers, together with the redesign of tanks, operating mechanism, supporting frames, with spring supports, produced a circuit breaker of approximately the same over-all dimensions and weight which by high-power laboratory tests proved to be adequate to interrupt the entire fault current of 16,000 amperes, rms, as determined by a-c network calculator studies of the system. The construction details of the circuit breaker are shown in Figure 2. Such extensive modifications in oil circuit breakers with so many years of service usually would not be economically justified. However, the large quantity of circuit breakers and the space and weight limitations imposed by their location on the bridges made this modernization the most practical solution of this particular problem.

The a-c network calculator studies were also the basis of application of instantaneous overcurrent relays for fault clearing by the line circuit breakers, of which there are more than 500, making this system one of the largest installations with this type of relay protection.

With the new relays and modernized circuit breakers, the fault clearing time has been reduced to 0.2 second with the attendant reduced maintenance costs, and improved system stability and reliability.

Digest of paper 48-170, "Circuit Breaker Modernization and Faster Fault Clearing on Single-Phase Electrified Railroad," recommended by the AIEE committee on switchgear and approved by the AIEE technical program committee for presentation at the North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

H. F. Brown is with the New York, New Haven, and Hartford Railroad, New Haven, Conn. **H. A. Travers** and **C. A. Woods, Jr.**, are both with Westinghouse Electric Corporation, East Pittsburgh, Pa.

Figure 1. A typical switching station

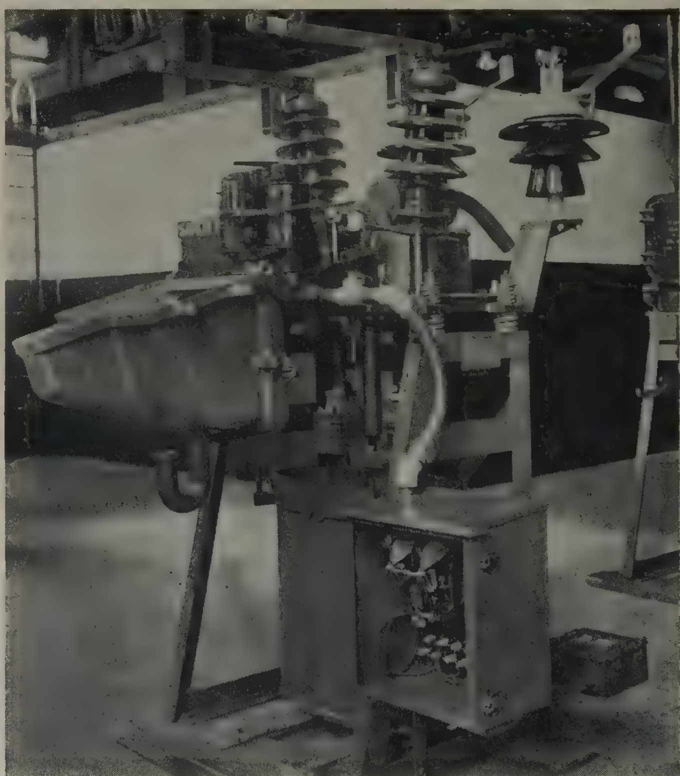

Figure 2. A modernized bridge-type oil circuit breaker

America's Future Power Needs

F. R. BENEDICT
ASSOCIATE AIEE

THE PRIME and mutual objective of the electrical manufacturers and the electrical utility industry is to make consumers conscious of the way electric power can work for them. This has been a long and arduous process. With the development of the a-c electric system, water wheels and steam engines were replaced by a whole new industry. Here was a new source of power which was clean, highly efficient, and almost constantly available. At first, progress was slow as the system development required a myriad of components; but with the development of reliable generation, transmission, distribution, and utilization equipment, this force of power became the backbone of American industry.

The United States as a nation is the greatest power consumer in the world, and more than half of this power consumption is represented by industrial customers. As industrialization advances steadily, consequently, so does the demand for electric power. The demand has been met in the past. Its future satisfaction can be accomplished only by a unified and highly integrated electrical industry.

It is of great significance that as a nation the United States is the greatest electric power producer in the world, but it is of far greater significance that the United States is the greatest power consumer in the world, for after all power consumption determines size and economic stature. A discussion of future power requirements of course must be a discussion of the electric power consumption capacity of the country, and in this the electrical utility industry and the manufacturers have mutual interets. This article will highlight some of the phases of industrial power consumption which have a direct bearing on the future growth of power in America.

Industrial customers represent more than half of the power consumption by all customers. In the 20-year period from 1926 to 1946, during which time the number of production workers increased 40 per cent, the kilowatt-hour consumption per industrial worker increased 120 per cent from 3,841 to 8,426 kilowatt-hours. Of this consumption, about 70 per cent is for motors and lighting. There has been a gradual but definite increase in the horsepower of individual industrial machines brought about by the need for higher efficiency in production. The progress made in the economy of production through process engineering is creating a wide spread between the most efficient and least efficient plants. Although marginal plants can be operated during periods like the present, theirs is at most a temporary opportunity, as competition will force a continued modernization program.

The ability of the human body to produce useful work is very low—about 1/50 horsepower per day. However, a 1-horsepower motor operating over the same period of time produces the power equivalent to 50 men. The introduction of power into industry shows continued increase. Of interest are recent figures that have been compiled on the amount of horsepower which backs up the American worker:

1849—very little
1879—1.3 horsepower
1909—2.9 horsepower
1929—4.86 horsepower
1939—6.4 horsepower
Present—7.2 horsepower

An historical study of these figures, which include both electric and mechanical power, shows that in 1909 about 2.0 of the 2.9 installed horsepower (about 69 per cent of the total) was mechanical, while in 1947 about 6.7 of the 7.2 installed horsepower (about 93 per cent of the total) was electric power. Thus a complete reversal took place in a span of about 40 years, with electric power now holding marked advantage over other forms of power. If the United States is to progress as a nation, the nation's productivity must increase, and to do this even more horsepower must be placed behind the worker. The application of electric power to industry today is advancing steadily, but as it advances the engineering problems are becoming more difficult. The horsepower figures quoted already indicate a high level of power behind the worker, and a new use of electric power must be justified from an economic standpoint.

Today, the words "from an economic standpoint" mean that the new power use must be justified in terms of the cost, quality, and quantity of the manufactured product. The determination of these factors is a complicated engineering problem and requires thorough study and evaluation of every manufacturing detail to determine whether the desired results can be obtained. At the present time the electrical manufacturers are giving a great deal of attention to this problem as industry is straining to attain the highest possible efficiency, and this efficiency can be obtained only by improving worker efficiency or machine efficiency.

With the greatly increased costs of labor, industry is looking with even greater favor now upon the application of highly specialized automatic machinery in industrial processes. According to the Bureau of Labor statistics, the average earned rate for hourly employees in all manufacturing industries in 1939 was 63 cents an hour. By November 1947, this rate had soared to $1.26 an hour. This labor cost increase has focussed the spotlight on any

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Essentially full text of an address, "Future Electric Power Needs of American Industry, presented at the Midwest Power Conference, Chicago, Ill., April 7, 1948.

F. R. Benedict is manager, industry engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa.

methods that can be used to help reduce production costs.

Of course the introduction of expensive machinery that turns out increased numbers of pieces at lower costs always has been a problem requiring intense worker education. This is because the worker thinks of the temporary decrease in manual labor required. But history definitely has proved again and again that such mass production techniques always result in increased worker income, a higher standard of living, and more jobs.

WELDING AND BRAZING

The whole problem of metals joining is being studied very thoroughly by industry at the present time. Faced with the problem of rising labor costs, every conceivable advantage must be taken in the fabrication of equipment to obtain the lowest possible manufacturing cost. Resistance welding is the process of joining metals wherein the heat of fusion is obtained by resistance to the flow of an electric current through the material being welded.

There are many interrelated reasons why the use of resistance welding is expanding and will continue to do so. The basic reason is that it is a time-saving joining method, particularly adaptable to high production manufacturing. Until about 1933 there was very little resistance welding of any metal except low carbon steel. This was because welding methods then in use were not very well controlled. The use of ferrous and nonferrous alloys was accelerated tremendously by the war, and it was necessary to develop new methods for welding aluminum, magnesium, and stainless and hardenable steels. This was made possible through the development of equipment for precision control of the welding current. While this load is intermittent and high, it is a most important one to industry. It should be emphasized that the use of resistance welding has not kept up with the increased use of new materials because of the lack of process information. As this is developed and disseminated, we will see resistance welding forge ahead. There is about 1,000,000 kva of this type of equipment already in service, and it is growing daily. The metal fabricating industries have a potential of more than three times this amount alone, and this potential could be reached quickly if fabrication materials became plentiful.

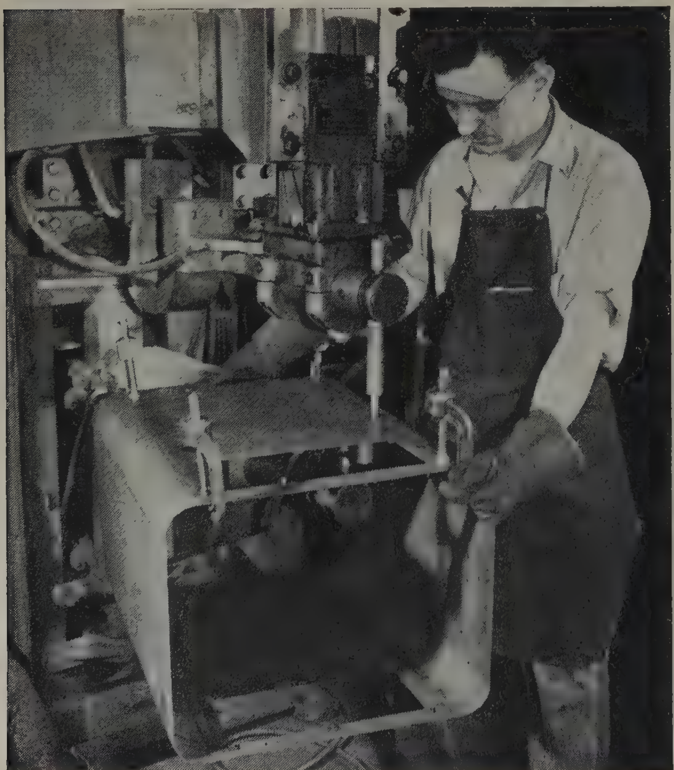


Figure 1. Spot welding sheet metal case made up of four parts: two side panels, a front panel, and a rear panel

Offsets along the edges of the side panels are used to position the front and rear panels. Speed clamps hold the pieces in place for spot welding

Figure 2. Unit heater cases being dried by a battery of 50 250-watt infrared lamps

This method of drying has cut the time required for this operation 75 per cent

During the war electric furnace brazing methods were developed to a high state of perfection, and industry is finding that today these methods can be integrated very well into their manufacturing operations. As these furnaces usually are worked on a continuous basis, they provide uniform loads that are very attractive. Industry already has installed about 50,000 kw of these furnaces and readily can absorb two or three times this amount.

For the brazing of small parts, where the time cycle can be short, induction brazing using high frequencies of 200,000 to 450,000 cycles per second has shown extreme utility. Similar high-frequency equipment also is coming into extensive use in hardening operations where accurate control of the depth of hardness is required. It is estimated that industry can absorb about 20,000 kw per year.

INFRARED HEATING

Infrared heating as yet has not reached its proper stature in the industrial field, in spite of the fact that the infrared

unit is in the form of a lamp with a low initial selling price and requires only moderate additional equipment for application. Infrared heat is versatile and can be used for drying many materials. It is used widely for drying paints and varnishes in all industries and finds about half of its applications in these fields. Other uses are developing rapidly in the textile, paper, and food industries. A careful review of the possible potential market for infrared heating indicates an industry absorption capacity of about

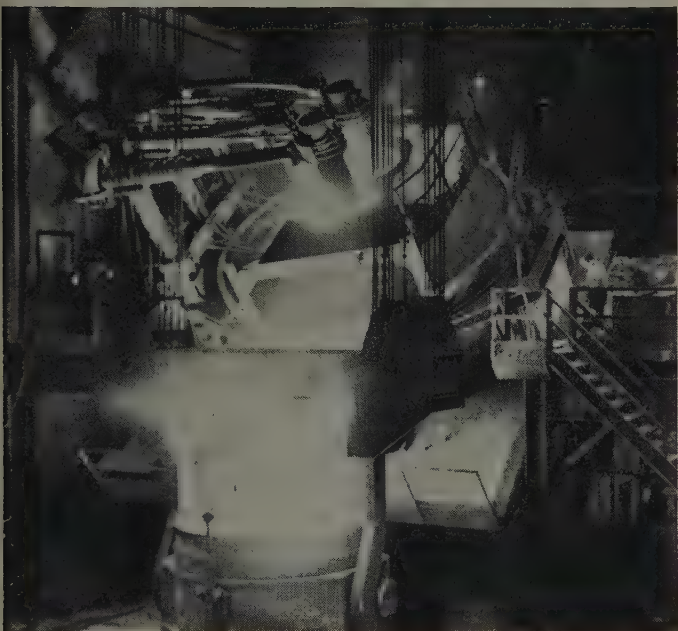


Figure 3. The electric furnace process affords very high temperatures with heat available quickly and at will, under fire regulation and control

Power for this 70-ton arc furnace is furnished by a 15,000-kva transformer

200,000 kw of this type of heating each year for the next ten years.

CONTINUOUS ANNEALING

Considerable interest is being shown in the continuous annealing of metal products of all types. In the cold rolling or forming of sheet metal products, the reduction of thickness produced by rolling, or otherwise forming, hardens the material. After a certain amount of cold work is done on the material, it must be annealed, and it then continues through its process. In some operations, it is necessary to anneal as often as five times during the process. If this annealing could be done on a continuous basis, considerable advantage could be obtained in speeding up the process, as it would eliminate many handling operations. Induction heating, using frequencies from 60 to 200,000 cycles, is being investigated actively and may find wide use in industrial processes within the next few years. The power consumption of such equipment will be high, possibly as much as 5,000 kw per unit, and will be a continuous type of load. The steel industry alone could absorb 1,000,000 kw of this type of heat in a relatively short time.

ELECTRIC ARC FURNACES

One of the largest single power consumers in the United States is the electric arc furnace. At the present time there is installed approximately 3,000,000 kw of this type of equipment, and the figure is growing rapidly. This type of furnace is ideal for making high-quality steel, and with the growing use of alloys it is due for considerable expansion in the future. A considerable portion of the energy now used is generated by the industry, but in the light of new developments, a higher proportion of this load will be purchased power. If American steel consumption continues to increase, there is a capacity in this field approaching 500,000 kw per year.

RESISTANCE FURNACES

Resistance furnaces with controlled atmosphere were used in large numbers during the war for continuous furnace brazing, annealing, and heat treating of all types of metal products. The largest user was the aviation industry, although the iron and steel industry was a close second. The absorptive capacity for this equipment is very high in industry, but here again a high degree of technology is necessary in making the application. As economy governs this application, very careful application practice must be followed.

It is estimated that industry can absorb 50,000 kw of this type of furnace equipment a year.

RADIO-FREQUENCY HEATING

As previously mentioned, radio frequencies from 200,000 to 450,000 cycles are used in the brazing and hardening field as applied to small metal parts. This type of heating also was applied during the war to the reflowing of tin on tin plate. Approximately 10,000 kw of radio-frequency

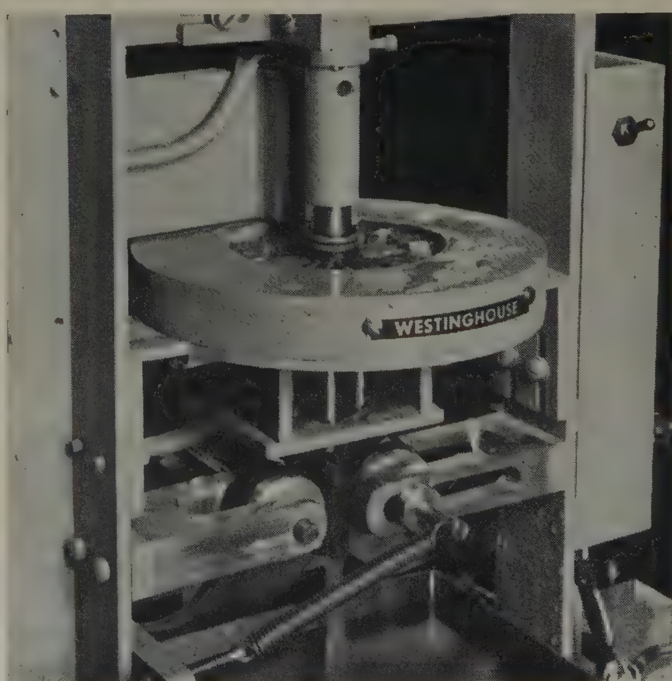


Figure 4. Induction hardening wrist pins

A pin can be seen passing through the 2-turn inductor coil and water quench while another pin is about to emerge from the speed controlling rollers below

heating at 200,000 cycles has been reflowing tin since 1943. This type of load is continuous and is usually on a 24-hour basis. If high output tubes in the order of 500 kw can be developed commercially, this type of heating will be attractive in the continuous annealing fields.

At the higher frequencies above two megacycles, two general fields appear to be most attractive. The first is in the heating of dielectric materials using frequencies up to 30 megacycles. This includes the curing of rubber, bonding of plywood, setting of glue, curing of plastics, and so forth. The practical fields are being established rapidly, and already about 5,000 kw of this type of heat is installed. The industry absorptive capacity appears to be about 10,000 kw per year. The second is the use of much higher frequencies—up to 1,000 megacycles. At low frequency, the power input to a dielectric is limited by the voltage that the dielectric can sustain. By increasing the frequency, the power input can be increased to levels that make continuous-process drying possible. However power equipment for these frequencies is not yet available, but the possibilities are so great that active experimentation is under way. If high-frequency drying can be extended economically to such fields as paper and textiles, absorption capacity will be tremendous.

FACTORY LIGHTING

It is estimated conservatively that 125,000 factories are underlighted, both in their offices and in their shops. It was only during the war that industry began to make comprehensive studies of the efficiency of workers under lighting conditions, and strangely enough these studies were brought about through the introduction of the fluorescent light and its higher output per watt. In factories where this type of lighting was installed, a high level of illumination was obtained, and factory efficiency soared to new levels that were previously thought impossible. This story must be brought to industrial customers on an engineering basis though, as an antiquated lighting system often results in the feeling that "what was good enough for Grandpa is good enough for me." Fluorescent lighting definitely pays off in worker efficiency and also simplifies many of the difficult problems of air conditioning. While the new lamps give $2^1/_2$ times the amount of light for the same watts, industry must be sold on the idea of increasing light levels at least four times over present levels for high worker efficiency.

ORE BENEFICIATION

American iron ore reserves are running out at an alarming rate. With the increase in steel production taking up some 3 million tons in 1947 and an additional 3 to 4 million tons scheduled for 1948, our present stocks of high grade ore will continue to be depleted at a high rate. It is estimated that the high grade ore will last only another 8 to 10 years, and already the United States is being forced to depend upon low iron content ores for a part of its supply. High-grade direct-shipping ores contain from 50 to 65 per cent iron, while lower grade ores may contain as little as 20 per cent iron. These are in two forms—the magnetic and the nonmagnetic types. At the present time the magnetic-type ore is favored for industrial development because of the simpler process required for economical recovery.

The development of this industry will require tremendous amounts of power, as every pound of ore will have to be handled many times in the process. Conservative estimates place the requirements for power of this industry at 1,000,000 kw. The rapid expansion of the industry will present many problems as most of the areas are not highly electrified and generation, transmission, and distribution facilities will have to be matched with utilization as it develops. As this development progresses, a definite increase in kilowatt-hours per unit of production will be realized.

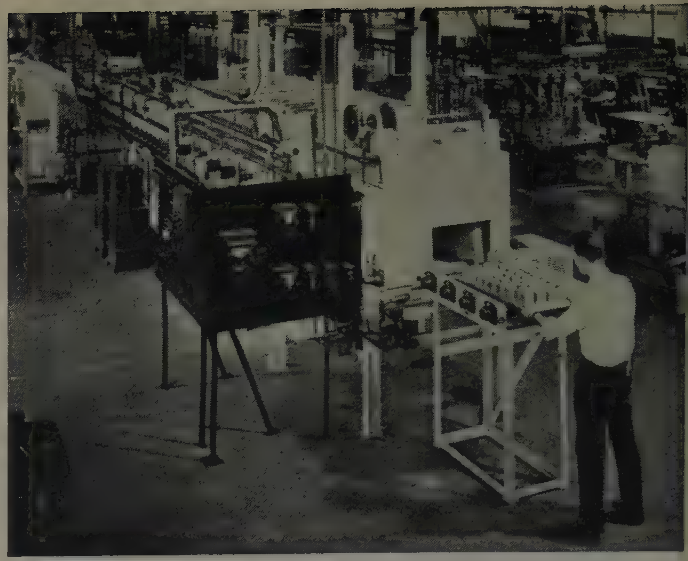


Figure 5. Charging a continuous roller hearth furnace for copper brazing of parts and assemblies too heavy for the conveyer belt type of furnace

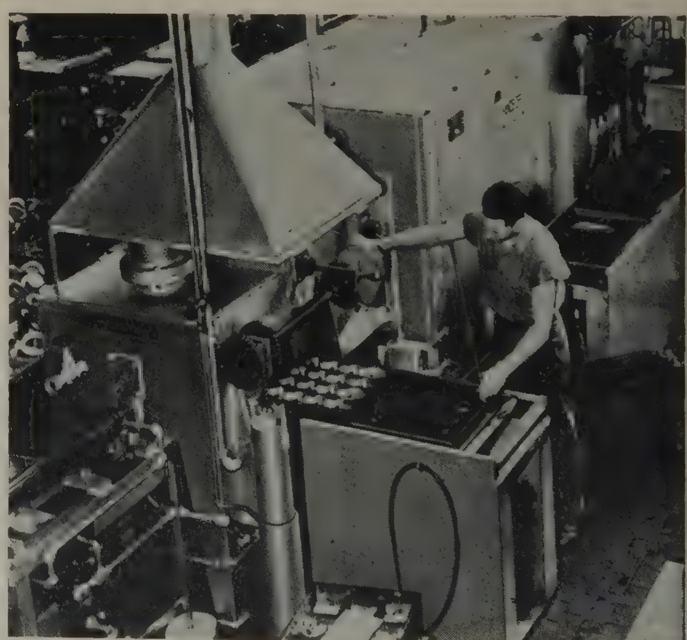


Figure 6. Production hardening of both large and small parts successfully is done in this pusher-type electrically heated hardening furnace

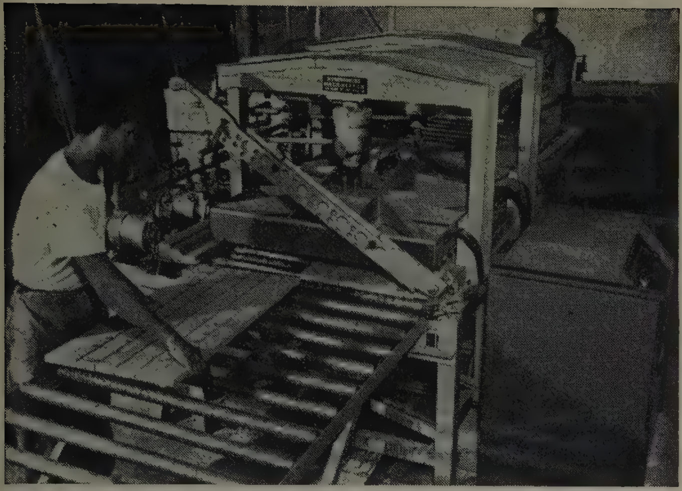


Figure 7. Removing glued stock from radio-frequency glue clamp

Setting times of one minute and less are possible with this form of heat

CHEMICAL INDUSTRY

The chemical industry, which includes not only the light metals such as aluminum and magnesium but the special chemicals such as chlorine and caustics, is a very large user of electric power. A large proportion of the energy used is direct current, which requires conversion equipment. The advantages of electric power over other forms of power long have been recognized in this industry, and it is now highly electrified. With new chemicals developed during the war just going into production, the industry is due for a large expansion. With industrial concerns eating up chemicals at a tremendous rate, the industry has not been able to keep up with the demand, and there have been shortages in some chemicals far more serious than the shortage of steel has been. This has not been caused by a shortage of electric power, but rather by a shortage of critical materials from which the chemicals are manufactured. The industry has an installed capacity in rectifiers of over 200,000 kw, and this is increasing daily.

Figure 8. Two-lamp 40-watt fluorescent units, four to a 25-foot bay, produce an average maintained intensity of 30 foot-candles in this roving machinery room

The fixtures are mounted 12 feet 6 inches above the floor

The development of the aluminum industry during the war was quite comparable to any of the "Seven Wonders of the World," not only in the speed with which it was accomplished, but also in the amount of rectifiers absorbed by the industry. Aluminum and magnesium played very important parts in the winning of the war, and at the end of hostilities it was expected that the United States would have more capacity in aluminum and magnesium than the country conceivably could require. At first production slumped off rapidly because of the closing of many of the high-producing aircraft plants, but the steel shortage was very instrumental in bringing out the advantages of aluminum for many types of products. Now the aluminum industry is nearly up to the capacity at which it operated during the war. Industrial designers just are beginning to recognize the very real advantages of aluminum. This industry is expected to continue at high capacity for some time; then, as aluminum finds its real place, there will be a gradual increase in production which will require large additional amounts of power. There is installed today in the aluminum industry about 1,500,000 kw of rectifiers alone, and this very conceivably could double within the next ten years. As this type of load is normally on a 24-hour basis, an equal amount of generation capacity would be required.

Magnesium, which first was developed on a commercial basis using the sea water process, has been slow to take hold in industry. Magnesium by itself is one of the lightest metals known for its strength, and when alloyed with other metals it gives a material which is both light and strong. It was used very widely in castings and in sheet form during the war, but it has not gained its expected popularity in the postwar picture. However, industrial designers are beginning to realize that they are failing to take advantage of one of the most versatile new metals available to them. It is likely that there will be a complete reversal in the use of this material within the next ten years. At the present time there is only one source of supply, and it is adequate for present needs. However, this industry has an installed capacity of about 400,000 kw. It is not at all inconceivable that the industry will double its power consumption within ten years.

MINING

The complete emancipation of the miner is under way. His has been one of the most hazardous and hardest jobs in all American industry. Coal has been the chief source of fuel in the United States since its beginning, but it has been in the last 15 years only that the advantages of mechanization in coal mines has been recognized as an engineering fact. Progress in mechanization has been rapid, and the kilowatt-hours per ton of coal mined has been increasing gradually until it is now about $6^1/_2$ kilowatt-hours per ton. There are no good estimates of the installed horsepower per worker in the mining industry, but it is estimated that it is now less than two horsepower per worker. In comparison with the factory worker who

enjoys about 7.2 horsepower, the miner with his lower horsepower backup still is required to put in a hard day's work. This picture is changing rapidly however, and it is recognized that the electrification of coal mines is a must. Industry has not been able to keep up with the demand for mechanized equipment, and there are still extremely large backlogs on machinery suppliers' books. Whether we like to admit it or not, coal is still "king," and full mechanization of the industry is in the offing. Such mechanization will require at least double the capacity now installed in the industry, and it very easily could go to three times the installed capacity.

PETROLEUM

America's oil shortage is acute, and it is expected to get worse before it improves. Petroleum products are being used in excess of the highest rate demanded during the war, and the absorptive capacity of the country hardly has been scratched. The uncertainty of the coal situation has thrown great emphasis on the use of oil and gas for both home and industrial heating, and this greatly has broadened the market for petroleum. The oil burner industry is manufacturing units at a rate of more than 2 million a year, and if the expected conversion rate is attained, this will increase to 3 or $3^1/_2$ million units a year. Power consumption in this field alone would approximate an additional billion kilowatt-hours a year until the market is satisfied. Because of its cleanliness and because it can be controlled automatically, the oil burner will find high favor for home and industrial heating, provided of course that the oil to satisfy the demand can be produced.

With the acute shortage of oil, engineers are looking to other oil supplies as well as trying to find new ways to increase the oil output. The kilowatt-hours per barrel of petroleum increased from 2.24 to 3.35 between 1939 and 1945, and the industry at the present time is only 14 per cent electrified. It has been shown that electric drilling rigs are highly efficient devices, and even though they are more expensive than mechanical rigs they show definite advantage in deep-well drilling operations. The Government has been carrying on extensive studies in the production of oil from oil shales, and if this should turn out to be economical (and there is every indication that it may), the industry may absorb as much as ten kilowatt-hours per barrel of oil produced. The potentialities here are tremendous, and absorption is highly dependent upon the development of satisfactory processes.

The dwindling oil reserves have thrown additional emphasis on the processing of coal to obtain oil and chemicals. This work is progressing very rapidly, and pilot plants are under construction. Such plants will use coal at a tremendous rate, and coal production must follow. Present capacity is in the order of 600 million tons a year, but this will have to double at least to supply this new industry if as little as 20 per cent of the oil is to be obtained from this source.

This article has not attempted to review all industry; consequently, many large power consumers have been omitted.

Industry is calling continually for increased amounts of power, which it is hoped can be supplied to everyone who desires it. The past demand largely has been unpredicted, and as a result the reserves are dwindling slowly. There are those who are wondering whether the consumption and production lines will cross. There are two primary reasons why they have not crossed up until now. The first is the interconnection of large power systems that has made it possible to supply maximum demands imposed on the system by exchange of power. The second is the present shortage of materials which has limited industrial production. This natural brake on the use of power is beginning to be released though, and the situation must be watched carefully.

The standard of living in the United States is the highest on earth and is going higher, and American citizens can be expected to expect more and more of electric power. Even today, if the lights in an American home go off for 24 hours, it is considered a minor catastrophe. One of the biggest problems of industry today is that of reviewing its operations with the idea of making all of them profitable. This involves a high degree of technology and engineering, and increasing amounts of both of these must be placed on the problem to attain maximum results. The forecasters undoubtedly are right in saying that electric power is on the increase and will continue to be on the increase as long as there is the need for it.

Nothing has been said in this article about atomic power and its effect on industry and the home, but when such power is developed commercially it certainly will react on American economy. As the United States Government has indicated that atomic power is at least ten years away, the nation should continue to build solidly for the future as it has in the past. This can be done only by a unified and highly integrated electrical industry, which will continue to give a high degree of service to its customers.

Mechanical Activation

A newly developed chemical technique known as "mechanical activation" that uses a metal-cutting process to produce a chemical reaction was reported by Doctor M. C. Shaw, Massachusetts Institute of Technology, Cambridge, Mass., at a meeting of the American Society of Mechanical Engineers.

A metal-cutting fluid encounters an unusual combination of conditions at the point of a cutting tool. It is subjected to high local pressures and temperatures, and nascent highly stressed metal surfaces. Such a combination in general will promote a chemical reaction.

During a study of the basic mechanism of cutting fluid action it was found that certain organic reagents when used as cutting fluids react vigorously with the metal cut even though relatively inert to the uncut metal in bulk. The discovery suggests the possibility of using a metal-cutting process to carry out reactions between metals and liquid or gaseous reactants and thus to produce many extremely versatile organometallic compounds (combinations of metals and carbon), ordinarily difficult to produce because of the inflammability and toxicity of the reactants and the difficulty of starting and controlling the reaction.

New Telemetering Devices

W. H. BURNHAM

Two new auxiliary devices, the torque balance load injector and the torque balance converter, have been designed for use with the torque balance telemeter and other types of telemeters. These developments will add greatly to the flexibility and performance of telemeter systems.

THE continued increase in remote indication of electrical and nonelectrical quantities in the United States and abroad has taxed the ingenuity of the engineer to provide new systems and auxiliary devices to meet their needs. One of the better known devices used for remote indication of electrical and nonelectrical quantities is the torque balance telemeter. The successful use of this telemeter has suggested the development of two pieces of auxiliary telemetering equipment which greatly broadens the field of application for this telemeter as well as serving to augment the general field of telemetering. These new devices, known as the load injector and the converter, working in conjunction with the torque balance telemeter provide the additional functions of signaling, and the totalizing and integrating of a telemetered quantity.

To understand the new adaptations, the basic device must be examined first. The torque balance telemeter is a type of servomechanism in which two opposing torques are used to achieve the proportionality between the measured quantity and the output current in milliamperes. Basically, the device contains an operating mechanism, a restraining mechanism, a photoelectric follow-up system, and a power supply. The operating mechanism will depend upon the quantity being telemetered. Figure 1 shows a functional analysis diagram of the device for telemetering power. In this instance, the operating mechanism, which is shown as the primary detector, is a wattmeter mechanism without the control spring. The restraining mechanism is a d-c milliammeter mechanism with very low torque lead-in spirals substituted for the control springs. Both mechanisms are connected to a common shaft which also supports a small mirror. A beam of light is reflected from the mirror onto two photoelectric tubes. The relative amount of light on the tubes determines the polarity and magnitude of the d-c output current from the power supply.

With no input to the operating mechanism, the beam of light is divided equally between the two photoelectric tubes and the d-c output current from the power supply is zero. When the operating mechanism is energized, the common shaft turns and the light reflected from the mirror illuminates one photoelectric tube more than the other, which causes the power supply to produce an output current. As the d-c output current flows through the restraining mechanism, it will produce a torque on the common shaft which, by virtue of proper lead connection, will be opposite to that produced by the operating mechanism. The output current will increase until these two torques are balanced. For this condition, there will be a definite distribution of light on the photoelectric tubes which means a certain value of output current for a given value of watts input to the operating mechanism will be established.

Essential substance of paper 48-44, "New Devices Derived from a Torque Balance Telemeter," recommended by the AIEE joint subcommittee on telemetering and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948; and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

W. H. Burnham is with the General Electric Company, West Lynn, Mass.

TORQUE BALANCE LOAD INJECTOR

With the many telemeter channels associated with a power system, channel outages are sure to occur occasionally. When this happens it is very desirable to have the indicating, totalizing, and recording circuits function normally and include the average values from the missing channel. (These values may be obtained by telephone.) It is also desirable to have a signaling system between the dispatcher's office and power stations to tell the individual generating stations what load they should be carrying. The effectiveness of this system is increased if alarm features are incorporated to call the station operator's attention to a change in required load.

These requirements are fulfilled by the load injector (Figure 2), which is essentially a manually adjustable d-c milliampere power supply with special features incorporated. The output of the power supply can be varied from 2 to 50 milliamperes and will remain substantially constant when once set, even with normal supply voltage variations or changes in the load resistance. This device also can be made having lower output ratings such as 1 to 25 milliamperes. Two major changes were made in the torque balance telemeter to produce this device. First, the power supply was redesigned to provide the increased output current; and second, the operating mechanism was replaced by two instrument control springs. By means of a gear linkage the control springs can be rotated by a knob on the front panel. The torque produced on the shaft by the springs produces the same results as any electrical operating mechanism and becomes the input. Except for this manual adjustment of the input, the operation is nearly identical with that of the torque balance telemeter. A reversing switch is included for selecting polarity of output current.

Variations of plus or minus ten per cent in the supply voltage result in only a plus or minus one per cent change in output current. The maximum value of load resistance into which it will operate with full output is 1,000 ohms, and the variation in output current throughout the range

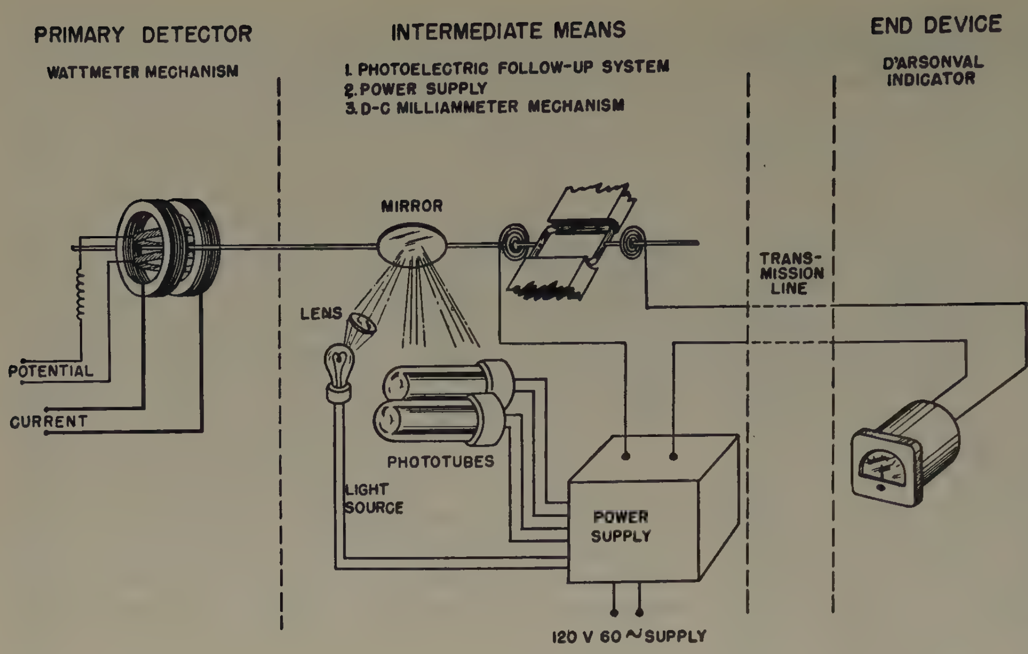


Figure 1. Functional analysis diagram of a torque balance telemeter for telemetering power

of 0 to 1,000 ohms load resistance is less than two per cent of full scale. The output control is not calibrated because the device is intended to be used with a milliammeter as a guide to the operator.

As a signaling device, the load injector may be located in the dispatcher's office and the receiving instrument in a generating station. With the instrument scale marked in units of load, the dispatcher can indicate to the station operator what load he should be holding.

TORQUE BALANCE CONVERTER

As previously mentioned, the output current of the torque balance telemeter representing the measured quantity can be indicated and recorded. However, when telemetering power, it is often desirable to know the amount of energy generated during a certain period. This information can be obtained only by using a planimeter on the recorder chart, or a similar method to multiply the average value of power by the time. A similar problem exists in obtaining an integrated reading of power flow over tie lines. As tie line power flow may be in either direction, it is necessary to integrate the area under the curve on each side of zero on the recorder chart and multiply by the time to obtain the resultant value and direction of the energy flow. When telemetering power, a very common requirement is that a reading be transmitted that represents the total of several power sources. If the telemeter transmitter operates on the watt-hour meter principle, some means of producing watts in proportion to the totalized reading must be used to operate the transmitter.

To solve these problems and provide directly a continuously integrated reading of the quantity from the output of a torque balance telemeter, the torque balance converter has been developed. If a quantity can be expressed in terms of watts, it can be integrated with respect to time by applying the watts to a watt-hour meter. The converter performs the conversion of d-c milliamperes to single-phase a-c watts. By applying these to a watt-hour meter, a continuously integrated reading of the original quantity is obtained. The converter, shown in Figure 3, consists of two components, the converter unit and a current amplifier. One of the wattmeter mechanisms is used as a variable ratio transformer. That is, the current coil is excited with its rated current and a voltage is taken off the potential coil. The magnitude and phase of this voltage depends upon the relative position of the potential coil with respect to the current coil. The other wattmeter mechanism is used as a watt restraining mechanism, and the milliammeter is the operating mechanism. The voltage induced in the secondary coil of the variable ratio transformer is the input signal to the amplifier. The load on the output of the amplifier consists of the current coil of the watt restraining mechanism and the current coil of a single-phase watt-hour meter in series. Their potential coils are excited from the 120-volt a-c supply.

With zero input to the converter, the variable ratio transformer has zero coupling and no signal is applied to the amplifier. Thus the output current is zero and no

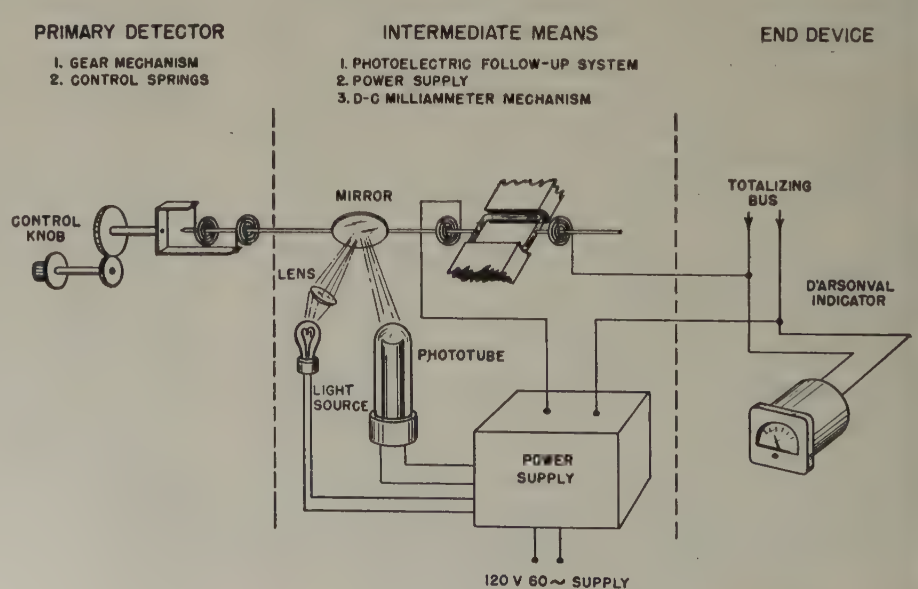
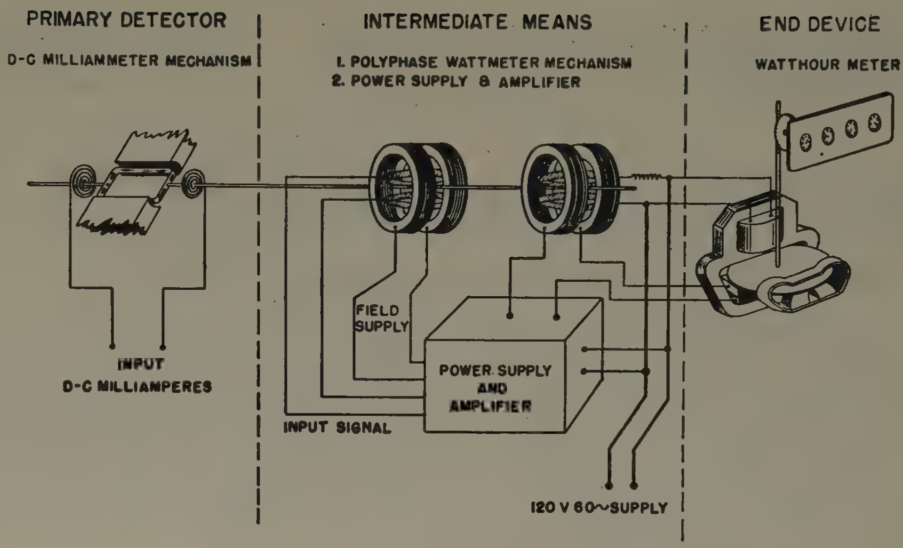


Figure 2. Functional analysis diagram of the torque balance load injector

Figure 3. Functional analysis diagram of the torque balance converter



power is applied to the watt-hour meter. As the common shaft is rotated by the operating mechanism, a signal is applied to the amplifier. The output current produces rotation of the watt-hour meter disk and causes a torque to be produced by the watt restraining mechanism in the converter unit. This torque will be opposite to that produced by the operating mechanism, by virtue of the proper connections to it. Therefore, the shaft will rotate until sufficient output current is flowing to establish a balance of these two opposing torques. When the balanced condition is obtained, a definite amount of power will be represented by the output current and the 120 volts supplied to the potential coils. If the input milliamperes to the converter is doubled, the output power will be doubled as a new balance is established. The watt restraining mechanism may be considered a monitor of the watts output as it determines the magnitude of output current for a given value of milliamperes input to the converter.

The error that is introduced by the nonlinearity of the watt restraining mechanism is held to a very small value by limiting the angle through which the shaft turns to only a few degrees. Normal line voltage variations have very little effect upon the conversion accuracy because the watt restraining mechanism will adjust the system by changing the output current.

If the polarity of the input d-c milliamperes is reversed, the power flow to the watt restraining mechanism and the watt-hour meter will reverse. This reversing feature makes the converter very adaptable to integrating tie line loads where power flow may be in either direction. The torque balance telemeter can be used in conjunction with the converter for this application inasmuch as it also has this reversing feature. In this instance two watt-hour meters with detents are connected in series so that each meter will integrate power flow in only one direction.

Progressive standardization has made the torque balance telemeter an attractive device for totalizing at the transmitting end of a telemeter channel. For this application, a torque balance telemeter may be connected to each generator through instrument transformers, for measuring watts or vars, and the outputs paralleled. The totalized d-c milliamperes then can be applied to the torque balance converter and the output watts applied to a watt-hour meter impulse-type transmitter, such as those used in several of the present systems. Even when thermal converters are used at the transmitting end, the torque balance converter is applicable if used in conjunction with a self-balancing potentiometer, which is a device that converts d-c millivolts to d-c milliamperes with high speed of response without moving parts other than a galvanometer.

Linear Accelerator

According to a recent report, Yale University physicists have attained energies of one million volts in a new type of linear accelerator. The device has been constructed under the supervision of H. L. Schultz, in collaboration with E. R. Beringer and C. G. Montgomery, all of Yale University, New Haven, Conn.

In operation, electrons are directed through a small hole in a series of round hollow evacuated pill boxes which are from three to seven inches long. The electrons are accelerated by 1,000-kw 600-megacycle 10-microsecond pulses fed to the pill boxes which act as cavity resonators. Each of the pill boxes has its own amplifier and all of the amplifiers are connected to a master source which controls the movement of the electron from the electron gun to the target.

Professor Schultz and his aides are building a pilot model which is expected to produce energies from 15 to 20 million volts by the middle of the year. Four major problems will be studied using the linear accelerator:

1. Electrons accelerated by the accelerator will be used to produce nuclear transmutations and the new products will be studied.

2. How fast an electron travels when it is passing near the nucleus of an atom is unknown. The forces involved in this reaction are neither electrical nor gravitational in character, but have energies many million times such forces. How does an electron get out of a nucleus and what are the peculiar fields of force are problems to be studied.

3. When a fast electron is stopped suddenly, X rays or gamma rays are produced. Theoretically, billion-volt X rays can be produced by the linear accelerator which will be very useful in nuclear studies.

4. Finally, the problem of how fast electrons are absorbed in matter will be investigated.

INSTITUTE ACTIVITIES

Tentative Program Announced for Summer Meeting in Mexico City

The program for the AIEE summer general meeting in Mexico City, June 21–25, 1948, will feature the latest trends and practices in the development of electric power and its applications to industries of particular interest to Mexican engineers. In addition, the annual meeting, the delegates get-together, the conference of vice-presidents and District secretaries, and a conference on Section operation and management will be held as usual, all amidst colorful surroundings of which the summer general meeting committee has taken full advantage in the arrangement of inspection trips and tours to many places of interest. Beginning with the official inauguration of the meeting on Monday, with entertainment each evening, and a reception to the president, a busy and enjoyable week is assured.

At the present writing, the Palace of Fine Arts, which previously was announced as headquarters for the summer general meeting, is unavailable except for perhaps one or two sessions. The main portion of the technical program will be presented, instead, at the new and very modern Teachers' College which is situated on Calzada Tacuba, in the suburbs of Mexico City. The college, whose buildings and grounds occupy approximately 660,000 square feet, was opened in November 1947, and was selected as the site for the UNESCO conferences held in Mexico City at that time. Several large halls at present occupied by offices and others which are not yet being utilized will be at the disposal of the AIEE for the summer meeting sessions.

TECHNICAL PROGRAM

In the development of the technical program the particular interests of Mexican engineers were determined by personal interviews and correspondence. Thus, technical sessions have been arranged to bring out the latest trends and practices in the applications of electricity to the production of steel, petroleum, mining, textiles, and paper. Developments in hydroelectric power and irrigation, power systems, and power transmission and distribution, as well as standards and apparatus, will be brought out in other sessions by well-known authors in a position to make authoritative presentations. Two sessions will be in the field of communication and another will deal with railroad transportation. Still others on technical education, research, electric welding, and electronics contribute basically to the entire electrical industry. Seventeen papers by Mexican engineers will present their problems and solutions and the mutual exchange of ideas will aid in industrialization.

WOMEN'S PROGRAM

In addition to the sightseeing trips available to all members and their families, a very attractive program for women or mixed audiences will feature a symphony concert, fashion show and tea, exhibition of native dances and costumes, talk and colored film on the growth of Paricutin Volcano, a reception and luncheon, and formal evening banquet. There will be ample opportunities also for guided shopping tours.

SPORTS

Golf. Members and guests who wish to play golf, will be extended special facilities to use the golf courses of the Mexico City Country Club at Churubusco, the Chapultepec Country Golf Club at the Lomas de Chapultepec, and the Azteca course located near Chapultepec Park.

Rowing. Boats may be rented at the Chapultepec Park lake. Inquiries should be made at the information desks for details.

Swimming. Arrangements have been made to permit members and guests at the meeting to make use of the swimming pool of Reforma Club, Lomas de Chapultepec, the Balneario Olimpico, and the Balneario Las Termas.

Horseback Riding. Those desiring to go horseback riding while in Mexico will be provided with suitable mounts at moderate rates. Details may be obtained at the information desks.

ADVANCE HOTEL RESERVATIONS

Members and guests who will attend the meeting should make hotel reservations several weeks in advance to allow for individual confirmation for those reservations before setting out to travel to Mexico City. Definite arrangements have been made to concentrate AIEE members and their guests in the following major hotels: Del Prado, Regis, Prince, Reforma, and Geneve. All reservations will be handled by the Mexico Section's local hotel committee. Reservations should be made by writing directly to "Hotel Reservation Committee," AIEE 64th Summer General Meeting, Palma 33, Despacho 210, Mexico D. F., Mexico. Members should express their preference for single room, double room, or parlor suite, and also should indicate approximately the range or preferred limit on desired room rate.

REQUEST-FOR-INFORMATION COUPON

Pertinent information pertaining to the meeting has been published in the February, March, and April issues of *ELECTRICAL ENGINEERING* in respect to methods of travel, requirements for entering and leaving the country, rate of exchange, hotel accommodations, and restaurants. If they have not done so as yet, members and guests who are interested in attending the meeting should fill out and return to AIEE headquarters the "request-for-information coupon" which appeared in the February issue of *ELECTRICAL ENGINEERING* on page 56A of the advertising section, and on page 58A of the March issue.

SUMMER GENERAL MEETING COMMITTEE

Officers of the summer general meeting committee making arrangements in Mexico City are as follows:

President, Oscar R. Enriquez; *vice-president,* Hector Martinez D'Meza; *secretary,* William H. Taylor; *treasurer,* Federico A. Nava; *director, technical program committee,* Basil Nikiforoff; *director, general attention committee,* Manuel M. de Lascuráin; *director, general service committee,* Rafael Rangel.

Directors of working committees are as follows:

Finance committee, G. Maryssael, J. de la Macorra; *sessions,* G. B. Doughman, A. Bourlón; *papers,* A. Páez Urquidi, G. Solís Payán; *technical visits,* B. Nikiforoff, C. Santacruz; *hotels,* P. Barona Soto, J. Rivera S.; *hospitality,* E. del Valle G., M. M. de Lascuráin; *trips and sports,* A. C. Enrile, C. E. Plumb; *Ladies,* Mrs. Lascuráin, Mrs. Nikiforoff, Mrs. Plumb; *transportation,* B. E. Arias, A. Carrión; *information,* E. Nieto Palacios, R. Rangel; *publicity,* Alfredo Christlieb, E. Rodríguez Mata; *registration and tickets,* Alberto Christlieb, R. E. Eberstadt.

SPECIAL INSTITUTE MEETING COMMITTEE

Members of the special Institute meeting committee are as follows:

C. S. Purnell, *chairman;* R. F. Danner, J. E. Hobson, R. K. Honaman, and H. M. Turner.

Mexico Offers Many Sightseeing Excursions

Founded about 1200, razed and rebuilt by Hernán Cortés, Mexico City today is a modern metropolis of more than two million inhabitants. In this true "land of contrasts," the colorful and ancient culture of an Indian-Spanish heritage stands side by side with the most modern products of contemporary civilization, offering to the visitor from the north all the flavor of a visit to a foreign country, and to the members of the AIEE an excellent opportunity to make the summer general meeting an unforgettable vacation.

WHAT TO SEE

The Zocalo. When the Spaniards arrived in Mexico City, they found a huge pyramid in the center of the city which housed the palace of the then reigning emperor, Montezuma. The pyramid was destroyed, and following Spanish custom, a large central plaza, the Zocalo, was laid out and the city rebuilt around it. The Zocalo today is flanked by the national palace, the cathedral, city hall, and various office buildings and department stores.

The Cathedral. The cathedral consecrated as the Church of the Asunción de Maria Santisima and known as the Holy Metropolitan Church of Mexico is said to be the largest church edifice in North America. Its cornerstone was laid in 1573 and work on the church was completed in 1667.

Schedule of Inspection Trips and Tours

Tuesday, June 22

7:30 a.m.	Inspection trip to the Miguel Aleman hydroelectric development, including the plants at Ixtapantongo and Santa Barbara, also the dams at Valle de Bravo and Colorines (return 7:00 p.m.)
8:00 a.m.	Trip through the industrial zone of Tlalnepantla and visits to the more important factories—Cía. Mexicana de Refractarios A. P. Green, and Cementos Anáhuac, S. A. (return 1:00 p.m.)
8:00 a.m.	City tour including visits to the principal government buildings, historic monuments, museums, and so forth, terminating with an inspection trip to the Cía. Hulera Euzkadi, S. A. (return 2:00 p.m.)
8:00 a.m.	Sightseeing trip to Churubusco, El Carmen, and El Desierto monasteries, terminating with an inspection trip to the water supply station at Xotepingo (return 2:00 p.m.)
8:00 a.m.	Visit to Real del Monte y Pachuca mines (return 3:00 p.m.)
8:00 a.m.	City tour (as afore-mentioned) terminating with an inspection trip to the Consolidada rolling mills (return 3:00 p.m.)
8:00 a.m.	Sightseeing trip to the floating gardens at Xochimilco terminating with visit to Ciudad Industrial D. M. Nacional (return 3:00 p.m.)
8:00 a.m.	Sightseeing trip to floating gardens at Xochimilco terminating with an inspection of Nonoalco substation (return 3:00 p.m.)
9:00 a.m.	Inspection trip to the Ayotla textile mills (return 12:30 p.m.)
9:00 a.m.	Inspection trip to glass factories (return 12:30 p.m.)
9:00 a.m.	Inspection trip through the studios and transmitting stations of *XEW* and *XEX* as well as the federal transmitting station at Chapultepec (return 1:00 p.m.)
9:00 a.m.	Excursion to ancient pyramids and historic Toltec ruins at San Juan Teotihuacán with visits to the Shrine of Guadalupe and the Acolman monastery (return 1:30 p.m.)
9:00 a.m.	Excursion to Cuernavaca with tour of city sights, including visits to the Cortés palace, Borda gardens, cathedral, San Anton waterfalls (return 3:00 p.m.)
9:30 a.m.	Afore-mentioned city tour (return 1:30 p.m.)
10:00 a.m.	Visit to Teléfonos de México, S. A. (return 1:00 p.m.)
10:00 a.m.	Visit to Cía. Telefónica y Telegráfica Mexicana (return 1:00 p.m.)

Wednesday, June 23

7:30 a.m.	Excursion to the Cacahuamilpa caves and Taxco with stopover at Cuernavaca (return 9:30 p.m.)
8:00 a.m.	Sightseeing trip to Churubusco, El Carmen, and El Desierto monasteries, terminating with an inspection trip to the water supply station at Xotepingo (return 2:00 p.m.)
8:00 a.m.	City tour (as afore-mentioned) terminating with an inspection trip to the RKO motion picture studios at Churubusco (return 2:30 p.m.)
8:00 a.m.	City tour (as afore-mentioned) and visit to the CLASA motion picture studios at Tlalpan (return 2:30 p.m.)
9:00 a.m.	Visit through studios and transmitting stations of *XEW* and *XEX* as well as the federal transmitting station at Chapultepec (return 1:00 p.m.)
9:00 a.m.	Excursion to Cuernavaca with tour of city sights, including visits to the Cortés palace, Borda gardens, cathedral, San Anton waterfalls (return 3:00 p.m.)
9:30 a.m.	Afore-mentioned city tour (return 1:30 p.m.)

Thursday, June 24

7:30 a.m.	Visit to power plants at Necaxa and Tepexic (return 8:30 p.m.)
7:30 a.m.	Excursion to Cholula and Puebla with a visit to the Manuel Avila Camacho dam and irrigation works at Valsequillo (return 9:30 p.m.)
8:00 a.m.	Visit to the Tlalnepantla industrial zone, Campos Hermanos, Reynolds Metals, and La Consolidada (return 1:00 p.m.)
8:00 a.m.	Tour of nearby monasteries (as afore-mentioned) and visit to Xotepingo pumping plant (return 2:00 p.m.)
8:00 a.m.	Visit to San Rafael y Anexas paper mills and tour in the vicinity of the volcanoes Popocatepetl and Ixtaccihuatl (return 3:00 p.m.)
8:00 a.m.	Visit to Real del Monte y Pachuca mines (return 3:00 p.m.)
9:00 a.m.	Inspection trip to the oil refineries of PEMEX at Atzcapotzalco (return 12:30 p.m.)
9:00 a.m.	Visit to afore-mentioned radio stations (return 1:00 p.m.)
9:00 a.m.	Afore-mentioned excursion to the pyramids (return 1:30 p.m.)
9:00 a.m.	Afore-mentioned excursion to Cuernavaca (return 3:00 p.m.)
9:30 a.m.	Afore-mentioned city tours (return 1:30 p.m.)
9:30 a.m.	Sightseeing trip to the floating gardens at Xochimilco (return 1:30 p.m.)
10:00 a.m.	Visit to Teléfonos de México, S. A. (return 1:00 p.m.)
10:00 a.m.	Visit to Cía. Telefónica y Telegráfica Mexicana (return 1:00 p.m.)
10:00 a.m.	Inspection trip to the factory of the Industria Electrica de Mexico, S. A. at Tlalnepantla (return 2:30 p.m.)

Friday, June 25

8:00 a.m.	Afore-mentioned city tour (return 12:00 p.m.)
9:00 a.m.	Afore-mentioned excursion to the pyramids (return 1:30 p.m.)

Postmeeting Trips

In addition to sightseeing trips in and around Mexico City, there will be a number of postmeeting trips to more distant places such as Cuernavaca, Taxco, Acapulco, Puebla, Cholula, Fortin, Paricutin, Patzcuaro, and others. Independent sightseeing trips and guide service can be provided by accredited travel agencies such as Wagon-Lits-Cook and Aguirre Travel Agency.

The interior is now in the process of reconstruction.

The National Palace. The National Palace houses various government departments such as the treasury, war department, and presidential offices. Of interest are the frescos by Diego Rivera.

Museum. The National Museum contains archaelogical specimens such as the original Aztec calendar; collections of early Indian pottery, and ancient work in gold, silver, and precious stones; and displays of pre-conquest Indian costumes, codices, and other objects of historical interest.

Palace of Fine Arts. Although originally planned as a national theater, the lavishly decorated palace is devoted mainly to various lectures and art exhibits. The back section contains the theater which is famed for its Tiffany glass curtain. Among the famous works to be seen here are frescos by Rivera and Orozco.

Chapultepec Castle. The castle, which overlooks the city from the top of a small hill at the entrance of Chapultepec Park, originally was built by the Spanish viceroy Matias de Galvez as a summer home in 1783. It subsequently became a military college, then the residence of the ill-fated Emperor Maximilian and Empress Carlotta. Today it houses the National Museum of History, as well as a display of the furniture, and so forth, of Maximilian and Carlotta.

Churches and Convents. Innumerable old churches are to be found in Mexico City, as well as many old homes. There is also a number of convents and monasteries built by the Spanish missionaries. Foremost among these are the Convento de Churubusco, the Convento del Carmen, founded in 1615, and the remains of El Desierto which was built in 1606.

Xochimilco. The famous "floating gardens" are really small islands which are planted with a profuse variety of flowers. The natives pole their flat-bottomed boats among the islands selling refreshments and flowers.

Cuernavaca. Once the favorite resort of Cortés and of Maximilian and Carlotta, now a fashionable weekend resort of Mexican citizens and tourists. Attractions include a golf club, many swimming pools, horseback riding and hunting, and shops where products of native arts and crafts may be bought.

(*Continued on page 489*)

Schedule of Events

Monday, June 21

9:00 a.m.	Registration
11:00 a.m.	Official inauguration of meeting
1:00 p.m.	Banquet at Mexico City Country Club
4:00 p.m.	Textile mill applications Technical education Applications to petroleum production Hydroelectric power and irrigation
9:30 p.m.	Concert by the Symphonic Orchestra of Mexico

Tuesday, June 22

7:30 a.m.	Inspection trips and tours
12:00 m.	Official reception by the mayor and governor of the Federal District to the board of directors and meeting executive committee
1:00 p.m.	Banquet for the board of directors and meeting executive committee
2:00 p.m.	Delegates get-together—luncheon at the University Club
4:00 p.m.	Conference of vice-presidents and District secretaries Applications to steel production Power systems Research Communication
4:30 p.m.	Fashion show and tea at the University Club

Wednesday, June 23

7:30 a.m.	Inspection trips and tours
10:00 a.m.	Annual meeting
3:00 p.m.	Guided shopping tours
4:00 p.m.	Conference on Section operation and management Rotating machinery Communication Industrial power systems and practices
7:30 p.m.	Reception tendered by the Ministry of Hydraulic Resources
9:30 p.m.	Typical and regional Mexican dances

Thursday, June 24

7:30 a.m.	Inspection trips and tours
9:30 a.m.	Board of directors meeting
2:00 p.m.	Board of directors meeting
4:00 p.m.	Illustrated lecture on the birth and development of the Paricutin Volcano Electric welding Mining operations Transmission and distribution Standards development
8:00 p.m.	President's reception, banquet, and ball

Friday, June 25

8:00 a.m.	Tours
9:30 a.m.	Paper mill applications Relaying and protective devices Electronics Railroad transportation
12:00 m.	Rodeo and amateur bullfight
5:00 p.m.	Reception by Ministry of Foreign Relations

Tentative Technical Program, Summer General Meeting,

Monday, June 21

9:00 a.m. Registration

11:00 a.m. Official Inauguration of Meeting

Reception to President Miguel Aleman of Mexico and cabinet members

Presidential salute

Rendition of national anthems

Welcoming address. Oscar R. Enriquez, chairman, 1948 summer general meeting committee

Address of welcome. Fernando Casas Aleman, governor of the Federal District and mayor of Mexico City

Address. Blake D. Hull, president, AIEE

Inaugural declaration. President Miguel Aleman of Mexico

4:00 p.m. Textile Mill Applications

48-142-ACO.* The Textile Mill Industry in Mexico. *Aurelio Lobatón*, Atoyac Textil and Ayotla Textil S. A.

48-114. Electrical Progress in the Textile Industry. *F. D. Snyder*, Westinghouse Electric Corporation

48-121. Induction and Dielectric Heating. *G. W. Scott, Jr.*, Armstrong Cork Company. The author will stress the dielectric heating aspects of the subject

4:00 p.m. Technical Education

48-143-ACO.* Technical Education and Its Trend in Mexico. *Juan M. Ramirez Caraza*, Escuela Superior de Ingenieria Mecanica y Electrica

48-144-ACO.* Psychotechnical Methods Employed to Select Personnel for Industries. *D. W. Mehl*, Telephonos de Mexico, S. A.

48-145-ACO.* Engineering Training—An Instrument of Progress. *A. G. Conrad*, Yale University

48-146-ACO.* The Impacts of Electronics on Engineering Education in the United States. *W. G. Dow*, University of Michigan

48-147-ACO.* International Aspects of Technical Literature. *E. P. Hamilton*, John Wiley & Sons, Inc.

4:00 p.m. Applications to Petroleum Production

48-148-ACO.* A Few Points on the Role of Engineers and of Petroleos Mexicanos in the Industrial Development of Mexico. *Luis Alfonso Guerrero*, Petroleos Mexicanos

48-149. Electrification of Petroleum Pipe Lines. *M. A. Hyde*, Westinghouse Electric Corporation

48-150. Oil Production by Electric Power. *W. G. Taylor*, General Electric Company

Movie: "Lease on the Future"—oil-well drilling, pumping, and pipe-line transportation. By courtesy of the General Electric Company (28 minutes)

4:00 p.m. Hydroelectric Power and Irrigation

48-152-ACO.* Hydroelectric Potentiality of Mexico. *Andres Garcia Quintero*, director of hydrology, Ministry of Hydraulic Resources of Mexico

48-151-ACO.* Full Utilization of Mexico's Hydraulic Resources through Multiple Purposes. *Adolfo Orive Alba*, Minister of Hydraulic Resources of Mexico

48-123. Grand Coulee Power Development. *S. M. Denton*, United States Bureau of Reclamation.

Tuesday, June 22

2:00 p.m. Delegates Get-Together

Luncheon meeting at the University Club

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; also, each is scheduled to be published in ELECTRICAL ENGINEERING in digest or other form.

4:00 p.m. Conference of Vice-Presidents and District Secretaries

4:00 p.m. Applications to Steel Production

48-141. Trends in Electrification of American Steel Industry. *L. A. Umansky*, General Electric Company

48-153-ACO.* Steel Industry in Mexico. *Carroll E. Plumb*, La Consolidada, S. A.

Movie: "Steel—Mans Servant." By courtesy of the United States Steel Export Company (35 minutes)

4:00 p.m. Power Systems

48-154-ACO.* Comments on the Development of Modern Power System Design Concepts and Operating Practices. *D. M. Jones*, General Electric Company

48-127. Change of Frequency on the System of the Southern California Edison Company. *H. W. Tice, A. A. Kroneberg, W. N. Johnson, J. D. Enefer, E. E. Tugby, C. L. Sidway*, Southern California Edison Company

CP. Trends in Power Generation Costs.** *A. E. Knowlton, Electrical World*

4:00 p.m. Research

48-155-ACO.* The Electrostatic Transformer and Its Possible Application to the Direct Utilization of Nuclear Energy. *Jose Mireles Malpica*, National Power Company

48-179-ACO.* Some Aspects of Research and Technological Development in Mexico. *F. W. Godwin, J. E. Hobson*, Armour Research Foundation

48-120. Formation of Oxide Films on Electrical Steel. *P. L. Schmidt*, Westinghouse Electric Corporation

4:00 p.m. Communication

48-140-ACO.* The Rotary Automatic Telephone System. *William Hatton*, International Telephone and Telegraph Corporation

48-156-ACO.* Development of Telegraph Communications in the Republic of Mexico—Recently Approved Project to Change and Modernize the Present Systems. *Jose Hernandez Olmedo*, Ministry of Communications and Public Works of Mexico

48-157-ACO.* The Intercommunication of the Ericsson and Rotary Automatic Telephone Systems of Mexico City. *Carl E. J. Danielsson*, Telefonos de Mexico, S. A.

Wednesday, June 23

10:00 a.m. Annual Meeting

President Blake D. Hull, presiding

Report of board of directors. H. H. Henline, secretary

Report of treasurer, W. I. Slichter

Reports of committee of tellers on votes for nominees for AIEE offices

Introduction of, and presentation of president's badge to Everett S. Lee

Response by Mr. Lee

Report on Institute prizes for papers. H. M. Turner, chairman, committee on award of institute prizes

Presentation of Lamme Medal to A. M. MacCutcheon

"The Establishment of the Medal." By the chairman or a member of the Lamme Medal committee

"The Career of the Medalist"

Presentation of Lamme medal and certificate by President Hull

Response by Mr. MacCutcheon

Any other business that may be presented

President's address. Blake D. Hull

4:00 p.m. Conference on Section Operation and Management

Review of the "Essential Activities of a Model Section." Prepared by F. S. Black

Report by subcommittee considering recommendations for a new set of prize paper rules. Chairman, F. S. Black

Report of subcommittee studying Sections finances. Chairman, Victor Siegfried

Report from the committee on membership transfers. Chairman, D. E. Moat

Consideration of the petition for a new Section by the group at Richland, Wash.

Such other business as may arise

4:00 p.m. Rotating Machinery

48-158-ACO.* Power Development in Mexico. *Alejandro Paez Urquidi*, Comision Federal de Electricidad; *Alfonso Fernandez del Busto*, The Mexican Light and Power Company, Ltd.; *German Garcia Lozano*, Nueva Compania Electrica Shapala, S. A.

48-130. Electrical Manufacturing in Mexico. *J. V. Schmill, R. M. MacGregor*, Industria Electrica de Mexico Cuidad Electrica

48-159-ACO*. The Equivalent Circuit and Constants for a Double Squirrel Cage Rotor Induction Motor. *R. C. Frese*, Industria Electrica de Mexico, S. A.

48-133. The "Superimposed Frequency Test" for Induction Motors, or S. F. Test. *M. P. Romeira*, General Electric Sociedade Anonima

4:00 p.m. Communication

48-131-ACO.* International Radio Telegraph Communications. *Sidney Sparks*, RCA Communications, Inc.

48-125. Mobile Radio. *Austin Bailey*, American Telephone and Telegraph Company.

48-132. A New 150-Kw Transmitter for Standard Band Broadcasting. *T. J. Boerner*, Radio Corporation of America

4:00 p.m. Industrial Power Systems and Practices

48-118. Trends and Practices in Modern Industrial Power-Distribution Systems. *W. C. Bloomquist*, General Electric Company

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48-160-ACO.* Industrial Group Builds Own Power Plant. *Vincente Aldape C.*, Planta Electrica Grupo Industrial

48-119. Central Utility Power Service Versus Local Plant Generation in Industry. *A. H. Frampton*, Hydro-Electric Power Commission of Ontario

Thursday, June 24

4:00 p.m. Electric Welding

48-121. Induction and Dielectric Heating. *G. W. Scott, Jr.*, Armstrong Cork Company. In this presentation induction heating aspects will be stressed

Movie: "Resistance Welding and Arc Welding." By courtesy of the Westinghouse Electric Corporation

Movie: "This is Resistance Welding." By courtesy of the General Electric Company

48-180. Resistance-Welding Machine and Power Supply. *C. E. Smith*, The Taylor-Winfield Corporation

4:00 p.m. Mining Operations

48-134. Utilization of Electric Power in Open Pit Copper Mining. *S. F. French*, Anaconda Copper Mining Company; *H. Speight*, Westinghouse Electric Corporation

48-181-ACO.* Trailing Cables for Mines—A Summary of Recent Papers. *E. W. Davis*, Simplex Wire and Cable Company

Movie: "Operations of the Cananea Consolidated Copper Company." By courtesy of Cananea Consolidated Copper Company

Movie: "Open Pit Copper Mining in Chili." By courtesy of the Chili Exploration Company

Movie: "Copper Mining, Smelting, and Refining—Montana Operations." By courtesy of Anaconda Copper Mining Company

4:00 p.m. Transmission and Distribution

48-124. Power Systems Overvoltages Produced by Faults and Switching Operations. *General systems subcommittee*, S. B. Crary, chairman

48-182-ACO.* Preliminary Report on Electric Power Distribution System Practices and Trends in the United States. *Distribution subcommittee*, Harold Cole, chairman

48-139-ACO.* Conductors—Types, Availability, and Use. *Subcommittee on towers, poles, and conductors*, A. E. Davison, chairman

48-126. Ten Years Performance of Lightning Resistant Wood-Pole Transmission Lines. *R. M. Schahfer, W. H. Knutz*, Northern Indiana Public Service Company

4:00 p.m. Standards Development

48-136. Standardization in the United States. *H. S. Osborne*, American Telephone and Telegraph Company

48-135-ACO.* Standardization by Electrical Manufacturers. *Frank Thornton, Jr.*, Westinghouse Electric Corporation

48-183-ACO.* Safety Codes as American Standards. *W. R. Smith*, Public Service Electric and Gas Company

48-137-ACO.* A Practical Application of Standard Apparatus—Factory Assembled Substations. *D. E. Craig, E. M. Hunter, L. D. Madsen*, General Electric Company

48-138-ACO.* Standards as Applied to Motors and Motor Applications. *W. R. Hough*, The Reliance Electric and Engineering Company

Friday, June 25

9:30 a.m. Paper Mill Applications

48-184-ACO.* The Paper Industry in Mexico. *Jose de la Macorra, Jr.*, San Rafael Paper Company

48-115. Electrical Developments in the Pulp and Paper Industry. *R. R. Baker*, Westinghouse Electric Corporation

48-185-ACO.* Electronic System to Control Speed and Tension in Paper Manufacturing Machines. *Angel Rosales de la Mora*, Cía. Industrial de Atenquique, S. A.

9:30 a.m. Relaying and Protective Devices

48-122. A Brief Review of Switchgear and Circuit Breaker Practice in the United States. *M. H. Hobbs*, Westinghouse Electric Corporation

48-186. Principles and Practices of Relaying in the United States. *W. E. Marter*, Duquesne Light Company; *E. L. Harder*, Westinghouse Electric Corporation

48-187. A Method of Selecting Inherent Overheat Protectors Based Upon Motor Design Information. *V. G. Vaughan*, Spencer Thermostat Company. The author will give an actual demonstration during this presentation

9:30 a.m. Electronics

48-128. Trends in Electronic Engineering. *D. G. Fink*, McGraw-Hill Publishing Company, Inc.

48-129. Trends in Electron Tube Design. *W. C. White*, General Electric Company

48-188. Mercury-Arc Power Converters in North America. *C. R. Marcum*, Westinghouse Electric Corporation; *L. W. Morton, H. C. Steiner*, General Electric Company; *H. Winograd*, Allis-Chalmers Manufacturing Company

9:30 a.m. Railroad Transportation

48-117. The Increasing Uses for Electricity in Land Transportation. *Charles Kerr, Jr.*, Westinghouse Electric Corporation

48-116. The Locomotive Traction Generator Comes of Age. *Richard Lamborn*, General Electric Company

*ACO: Advance copies only available; not intended for publication in *TRANSACTIONS*.
**CP: Conference paper; no advance copies are available; not intended for publication in *TRANSACTIONS*.

(*Continued from page 487*)

Cacahuamilpa Caverns. The largest known caves in Mexico, are still partly unexplored. The formation resembles that of Kentucky's Mammoth Cave.

Taxco. Protected by the government as a national historical zone, the city of Taxco retains the outer aspect of the 16th century. Known for its silver jewelry, and for its leather goods and baskets.

Cholula. Famous for a huge and partially uncovered pyramid topped by a chapel. The vicinity has numerous churches, outstanding of which is the Capilla Real with its 49 domes.

Puebla. Third largest city of Mexico, not far from the volcanos Ixtaccihuatl and Popocatepetl. Local tile factories are open to the public, and at the entrance to the city are several public sulphur baths.

The Pyramids. En route to the pyramids is the world-famous Shrine to Our Lady of Guadalupe in which hangs the original Image of Our Lady of Guadalupe, or the dark-faced Image of the Virgin Mary, and also the Monastery of San Agustin Acolman, built in 1539. About 27 miles from Mexico City is San Juan Teotihuacan, or the place "where the Gods are adored." Here are the pyramids to the Sun and Moon, and the Citadel with its Temple of Quetzacoatl. A museum has been built on the grounds.

Pacific General Meeting to Be Held in Spokane

Spokane, Wash., will be host to the Pacific general meeting to be held August 24–27, 1948, with headquarters in the Davenport Hotel. Spokane, surrounded by a region of clear mountain lakes and within a day's easy motoring of seven national parks, provides an ideal setting for the meeting with the possibility of combining attendance with a few days vacation. An all-day trip is planned to Grand Coulee Dam and the Columbia River Basin project.

Those who have not been to Spokane since the war will find three large plants that have come into being for the manufacture of light metals; an aluminum rolling mill at Trentwood, and an aluminum reduction plant and magnesium plant at Mead. The rolling mill is one of the three largest in the United States and there are 32 furnaces in the melting department. The capacity is 288,000,000 pounds of finished aluminum plate, sheet, and strip products a year, and the Mead plant is rated to produce 216,000,000 pounds of aluminum ingot annually. Both plants are in full production by the Henry J. Kaiser interest's Permanente Metals Corporation.

A technical program is being developed to meet the needs of western engineers and papers will be presented which deal with power transmission, high-voltage distribution, power system operation, electric heating, air transportation, and electronic developments. Also included will be a golf tournament and other features. There will be ample opportunity for recreation amidst pleasant surroundings.

Committees Appointed for AIEE 1949 Meetings

Two general committees have been appointed by AIEE President Hull to make plans for forthcoming AIEE general meetings. The 1949 winter general meeting will be held in the Pennsylvania Hotel, New York, N. Y., January 31–February 4, 1949. The general meeting committee for this meeting includes the following personnel:

A. E. Knowlton, *chairman*
G. J. Lowell, *vice-chairman*
H. E. Farrer, *secretary*
W. J. Barrett, *budget co-ordination*
R. T. Oldfield, *hotel reservations*
R. W. Gillette, *inspection trips*
H. M. Turner, *technical program liaison*
J. J. Pilliod, *general sessions*
A. E. Knowlton, *medal awards co-ordination*
D. T. Braymer, *registration, meetings*
R. K. Honaman, *press relations*
C. S. Purnell, *reception and tea*
A. J. Cooper, *smoker*
E. T. Farish, *dinner,dance*
T. J. Talley III, *theater, radio*

The 1949 Pacific general meeting is to be held in San Francisco, Calif., August 23–26,

1949. The general meeting committee for this meeting includes:

George C. Tenney, *general chairman*
C. E. Baugh, *vice-chairman*
Joseph A. Robinson, *secretary*
W. F. Poynter, *treasurer*
J. L. Buckley, *registration*
D. I. Anzini, *program*
R. O. Brosemer, *hotel*
I. W. Borda, *entertainment and reception*
W. J. Warren, *student activities*
W. R. Nodder, *trips and local transportation*
H. C. Verwoert, *transportation*
W. L. Winter, *sports*
Remi Bollaert. *publicity*

The duties of these committees and the relations between them and the technical program committee are covered by section 28 of the bylaws of the Institute.

Committees Announced for Midwest General Meeting

Announcement has been made of the appointment of committees for the 1948 AIEE Midwest general meeting, to be held in Milwaukee, Wis., October 18–22. Members of the general committee are as follows:

E. W. Seeger, *chairman;* E. U. Lassen, *vice-chairman;* E. F. Mekelburg, *secretary;* J. A. Potts, *treasurer;* L. C. Aicher; M. A. Baker; Kenneth R. Brown; Carl C. Crane; Everett H. Davies; Truman G. Glenn; F. C. Holtz; A. J. Krupy; John H. Kuhlmann; Ray Neighbours (*alternate,* L. F. Stauder); J. C. Strasbourger; H. M. Turner

Committee chairmen are

B. F. Tellkamp, *entertainment;* F. W. Bush, *finance;* E. J. Limpel, *inspection trips;* Mrs. E. L. McClure, Mrs. E. W. Seeger, *ladies' entertainment;* E. T. Sherwood, *publicity;* Ralph Earle, *registration and housing;* W. O. Helwig, *sports;* Walther Richter, *technical program,* E. W. Hatz, *transportation*

Future AIEE Meetings

Summer General Meeting
Teachers College, Mexico City, Mexico
June 21–25, 1948
(*Final date for submitting papers—closed*)

Pacific General Meeting
Spokane, Wash.
August 24–27, 1948
(*Final date for submitting papers—June 10*)

Middle Eastern District Meeting
Hotel Statler, Washington, D. C.
October 5–7, 1948
(*Final date for submitting papers—July 21*)

Midwest General Meeting
Schroeder Hotel, Milwaukee, Wis.
October 18–22, 1948
(*Final date for submitting papers—August 3*)

AIEE Conference on Electronic Aids to Medicine
New York, N. Y.
Fall, 1948

Southern District Meeting
Birmingham, Ala.
November 3–5, 1948
(*Final date for submitting papers—August 20*)

Winter General Meeting
Pennsylvania Hotel, New York, N. Y.
January 31–February 4, 1949

An Invitation from the Mexico Section

Considerable enthusiasm has been shown by a great number of AIEE members toward conducting the 64th AIEE summer general meeting in Mexico City, Mexico. The Mexico Section has received numerous letters from all parts of the world demonstrating the same spirit of enthusiasm and indicating that many members of the Institute residing abroad desire to attend the meeting, all of which is ample proof of the good will which members of the Institute entertain for their fellow Mexican engineers.

The Mexico Section, through its organizing committee charged with arrangements for the 64th summer general meeting, desiring to reciprocate these demonstrations of good will, extends hereby a most cordial invitation to AIEE members in the United States, Canada, Central and South America, Europe, Asia and Africa, and Australia, to attend the meeting and to participate in the many pleasurable and instructive events that the program includes. Those who accept by their presence will contribute inmeasurably to the success of the meeting.

As chairman of the summer general meeting committee in Mexico, I wish to assure all who are able to come that the length of the journey will be more than compensated for by the technical information provided by the papers read and discussed at the meeting, as well as by knowledge gathered about Mexico—to say nothing of social events and entertainment which the Mexico Section has prepared for those who attend.

It is the sincere hope of all those in charge of the meeting that as many as possible will accept this invitation and by so doing, not only have an opportunity to get to know Mexico, but to become familiar with a country whose engineers and others are dedicating their best efforts to promote the cause of human progress.

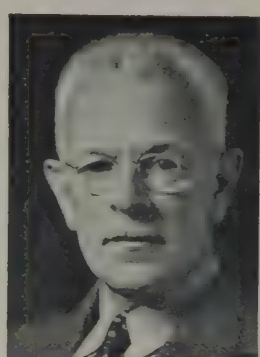
The following members of the 1948 AIEE summer general meeting committee in Mexico are directing preparations for the meeting which will take place, June 21–25. In addition to the committee members pictured, Federico A. Nava, salesman, Westinghouse Electric International Company, Mexico, is treasurer of the summer meeting committee


O. R. Enriquez

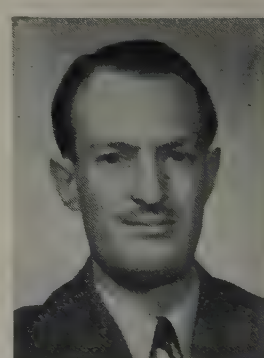

H. Martinez D'Meza


W. H. Taylor

Oscar R. Enriquez, head of the mechanical and electrical department of Mexico's Ministry of Hydraulic Resources, is president of the summer general meeting committee . . . Hector Martinez D'Meza, special representative of the Bank of Mexico in Washington, D. C., and chief of the imports and exports department, Mexican Embassy, Washington, is vice-president, summer general meeting committee . . . William H. Taylor, president, General Electric, S. A., Mexico, is secretary, summer general meeting committee . . . Basil Nikiforoff, chief electrical engineer, Mexican Light and Power Company, is director of the general technical program committee of the summer general meeting . . . Rafael Rangel, assistant general manager, Sociedad Electro-Mécanica, S. A., is director of the committee on services of the summer general meeting . . . Manual M. De Lascuráin, manager, Lascuráin y Mier Company, consulting and contracting engineers, is director of the general attention committee


Basil Nikiforoff


Rafael Rangel


M. M. De Lascuráin

Mexico
Land of Contrasts

(Above) The Teachers' College in Mexico City, headquarters for the summer general meeting in lieu of the previously announced site, the Palace of Fine Arts, which will not be available

(Left) An interior view of the Teachers' College

(Lower left) San Rafael paper mills, Amecameca, Mexico

(Lower right) Air view of one of Mexico's famed pyramids at San Juan Teotihuacan

(Right) Two giant power units, 31,000 kva each, at Ixtapantongo power plant

(Above right) The ruins of Tula

(Top right) A maid of Mexico

Milwaukee—Midwest Meeting Site

The City Hall in Milwaukee, Wis., which will be the host city for the 1948 AIEE Midwest general meeting, to be held October 18–22 with headquarters at the Schroeder Hotel

AIEE Board of Directors Meets During Winter Meeting

A regular meeting of the AIEE board of directors was held at the William Penn Hotel, Pittsburgh, Pa., January 29, 1948, during the winter general meeting of the Institute.

At this meeting, President Hull reported that, pursuant to action of the directors on November 5, George Sutherland had been appointed a representative of the Institute on the Library Board of United Engineering Trustees, Inc., for the 4-year term ending in October 1951, succeeding G. L. Knight. Also, a resolution was adopted in memory of Past President Cummings C. Chesney, who died on November 27, 1947 (*EE, Mar '48 p 291*).

ACTIONS ON MEMBERSHIP AND STANDARDS

Actions of the executive committee on applications for admission, transfer, and Student membership, and on recommendations of the Standards committee, were reported and confirmed. The actions pertaining to Standards matters were as follows:

Approved as an AIEE Standard, report on "Roof, Floor, and Wall Bushings," prepared by a subcommittee of the Standards committee.

Approved as an AIEE Standard, report on "Potheads," prepared by a subcommittee of the Standards committee. Approved submission to the American Standards Association with recommendation for approval of proposed "American Standard for Letter Symbols for Physics," developed by a subcommittee of ASA sectional committee *Z10*.

Approved the appointment of the following AIEE representatives: H. R. Stewart to sectional committee *C5*. "Code for Protection Against Lightning"; Frank V Smith to AIEE-American Society of Mechanical Engineers joint committee on turbine generator standardization; R. A. Frye to sectional committee *B32*, "Wire and Sheet Metal Gauges."

Recommendations adopted by the board of examiners at meetings on November 20 and December 18, 1947, and January 15, 1948, were reported and approved. The following actions were taken upon recommendation of the board of examiners: 15 applicants were transferred and two were elected to the grade of Fellow; 29 applicants were transferred and 72 were elected to the grade of Member; 178 applicants were elected to the grade of Associate; 975 Student members were enrolled.

S. M. Zubair was appointed local honorary secretary of the Institute for Southern India, to succeed N. N. Iengar, who had resigned because of removal from that territory.

FINANCES

Report by the finance committee of expenditures from general funds was approved as follows: $59,159.50 in November, $47,185.76 in December, and $51,125.19 in January. The committee reported that the income thus far this appropriation year (which began October 1, 1947) is slightly lower than was expected when the budget was adopted, and that some expenses are higher because of increased costs of printing and paper.

Members in arrears for dues for the fiscal year which began May 1, 1946, were dropped from membership, with the provision for reinstatement without the formality of an application if dues in arrears are paid prior to May 1, 1948.

The directors voted to continue during the fiscal year beginning May 1, 1948, the provision now in force for granting members in countries affected by abnormal exchange rates, an exchange allowance in the payment of dues corresponding to the difference between the New York exchange value and the normal par value of the countries in question, such allowance not to exceed 40 per cent of the dues payable and not to apply to purchases of or subscriptions to Institute publications; a corresponding reduction in appropriation payments to be applicable to Institute Sections in any countries affected.

Members in foreign countries, to whom "inactive" status was granted during the war because it was impracticable for them to pay dues, who still are being carried on this list, were dropped from the membership rolls, with the privilege of reinstatement upon application made prior to April 30, 1948.

FUTURE MEETINGS

A resolution was adopted setting the time and location of the 1948 AIEE annual meeting at Wednesday, June 23, in Mexico City, Mexico.

The following meetings were authorized as recommended by the committee on planning and co-ordination:

1949 District 7 meeting, Dallas, Tex., April 20–22

1950 District 1 meeting, Providence, R. I. (date not set)

1950 District 2 meeting, Baltimore, Md., in October

1950 Midwest general meeting, Oklahoma City, Okla., between October 15 and November 15

Upon recommendation of the committee on planning and co-ordination, the board of directors authorized the establishment of a

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full, formal text of a technical paper including discussion if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb. '47, pp 190–1	Feb '47, pp 33A and 34A
North Eastern District	Apr '47, pp 401–02	June '47, pp 55A and 56A
Summer General	June '47, pp 607–14; July '47, p 708	
Pacific General	Aug '47, pp 840–2	Dec '47, pp 55A and 56A
Middle Eastern District	Sept '47 pp 925–7	
Midwest General	Nov '47, pp 1125–8	
Winter ('48)	Jan '48, pp 76–87	Apr '48, pp 49A and 50A

new technical "committee on computing devices," with the following scope:

The treatment of all matters in which the dominant factors are the requirements, design, construction, selection, installation, and operation of machinery and devices relating to computing devices, including studies of the electromagnetic, electronic, and mechanical phenomena of such devices.

Fundamental mathematic, electronic, and properties of materials entering into these devices are not included.

Upon recommendation of the Standards committee, approval was given to the appointment of the following AIEE representatives: Thomas R. Weichel as AIEE representative on the mining standardization correlating committee, ASA, for the 2-year term beginning January 1, 1948 (reappointment); K. E. Hapgood as an additional AIEE representative on ASA sectional committee C29 "Insulators for Electric Power Lines."

AMENDMENTS TO CONSTITUTION

Amendments to the constitution, proposed by the committee on constitution and bylaws, were approved for submission to the membership for vote. The following amendments to the bylaws were among thoses adopted upon recommendation of that committee.

The words "(Journal of AIEE)" were deleted from Sections 6, 7, 22, and 63.

The heading "Life Membership" above section 21 was deleted, and the following was substituted for the three paragraphs of section 21:

All amounts now held to provide for the payment of dues of Life Members heretofore made shall be placed in the special fund designated as the "Life Membership Fund." This fund shall be so administered as to insure a reserve at the beginning of the fiscal year of a value such as to provide an annuity sufficient to cover the membership dues for life, based on the American Annuitants' Mortality Table, for all surviving contributors to the fund at their then attained ages. Any excess in the principal of the fund above the amount so required shall be transferable to the general funds of the Institute.

The table headed "Life Membership Rates" was deleted from this section. (The amendments to Section 21 will become effective when the constitutional amendment deleting the provision for the purchase of life membership goes into effect, July 23, 1948.)

The second paragraph of section 23 was amended to change the time of mailing the election ballots to the membership from "during the first week in April" to "on or before April 15."

By changes in the first and last two sentences, section 33 was amended to read as follows:

Each District executive committee may appoint from its membership a small continuously functioning co-ordinating committee consisting of the vice-president as chairman, the District secretary, four Section officers and the chairman of the District committee on Student activities who shall serve for a term of one year. The four Section officers and the chairman of the district committee on Student activities shall be eligible for reappointment if they continue as Section officers and chairman of District committee on Student activities, respectively, during the following year. Such a co-ordinating committee of seven shall function continuously in an executive capacity for the District executive committee. It shall co-operate with Institute headquarters, the Sections Committee, all Sections in the District, the Committee on Student Branches, all Branches in the District, with similar committees in other Districts, and through the District meeting committee with the Technical program committee.

Section 35, second paragraph. The first sentence was changed to read:

Upon expression by a District executive committee of a desire to hold a District meeting, and approval by the board of directors, the responsibility of the meeting shall rest with a District meeting committee appointed by the vice-president, and composed of membes within the District, preferably located in the area where the meeting is to be held.

The word "national" was deleted in the third sentence of the second paragraph of section 35 and changed to "general" in the fourth sentence.

In section 65, under the heading, "General Committees," were added the committees on education, management, Members-for-Life fund, Institute publicity, and transfers, and under the heading "Technical Committees," were added the new committee on computing devices, and the word "applications" to the name of the committee on chemical, electrochemical, and electrothermal.

The following was added as next to the last paragraph of section 65, effective upon adoption by the membership of the proposed constitutional amendment transferring from article VII, section 44, of the constitution to the bylaws of the provision for appointment of members of the board of directors to committees:

Each co-ordinating committee shall include at least one member of the board of directors.

Section 68, first paragraph, was changed to read:

The technical program committee shall consist of not less than nine appointed members, together with ex-officio members including the chairman of each technical co-ordinating committee, the chairman of each technical committee, and the chairman of each of the following committees: education, planning and co-ordination, research, safety, and Standards.

The following new section, defining the scope of the transfers committee, was adopted:

The transfers committee shall consist of not less than ten members, including a chairman, a vice-chairman, and a secretary; also the chairmen of the committees on transfers of the Sections of the Institute, ex-officio. This committee shall encourage the Sections to establish and maintain in continuous operation their own local committees on transfers. This committee shall maintain a guide for the committees on transfers of the Sections to insure smooth, continuous, and uniform functioning of the committees to the end that qualified Institute members will be encouraged to apply for advancement to higher grades of membership. This committee shall co-operate with the committees on transfers of the Sections in all suitable ways, and shall act as a medium of exchange of ideas among them.

In section 70, the first sentence was amended to read as follows:

The committee on planning and co-ordination shall consist of the chairman who shall be appointed by the president from the board of directors, the secretary, such other members as the president may appoint, and the chairmen of the following committees ex-officio: constitution and bylaws, finance, publication, Sections, Standards, technical program, and each co-ordinating committee.

Section 97 was changed to read:

A paper or discussion may be revised editorially under the direction of the technical program or the publication committee, but shall be returned to the author for his consent to publication as revised. In the event of disagreement, the author and the technical program or publication committee shall work out a mutually satisfactory arrangement before publication by the Institute.

PROFESSIONAL GROUP RESOLUTIONS

Upon recommendation of the professional group co-ordinating committee, the following resolutions were adopted in response to a request to the Institute to be represented on the National Security Committee, formed as a result of sessions held last fall, in Washington, D. C., of the Citizens Emergency Committee for Universal Military Training:

RESOLVED: That the American Institute of Electrical Engineers has taken no general stand on the subject of universal military training. However, the legislation which has been introduced to date does not adequately recognize the importance of specialized technical training and proper use of technically-trained personnel to the national security. Therefore, the Institute postpones the appointment of a representative to the National Security Committee until new legislation is to be drafted or the proposed bill is to be amended.

FURTHER RESOLVED: That the AIEE is willing to work with this or any other organization in the preparation of a training program which adequately would protect the national security through the use of technically-trained personnel in the pursuits where they are best fitted in either civilian or military posts.

The directors ratified an enabling amendment to the Constitution of the American Standards Association to make provision for seeking either a Federal or State charter for the association.

An invitation was accepted for the Institute to be represented by two delegates at the annual meeting of the American Academy of Political and Social Science to be held in Philadelphia, Pa., April 2–3, 1948. Chairman W. R. Clark of the Philadelphia Section was appointed as one representative with the request that he appoint the other delegate.

SECTION CHANGES

The following changes in Section territories were made:

The Territory of Alaska was assigned to the Seattle Section.

The following counties in New Hampshire were transferred to the Boston Section:

From Lynn Section—Belknap, Rockingham, Strafford

From Worcester Section—Cheshire, Sullivan, Grafton

Harrison and Jefferson Counties in Ohio were transferred from the Pittsburgh Section to the Canton Section.

Upon recommendation of the publication committee, based on a questionnaire poll of leading active members of the Institute (committee chairmen, national, District, and Section officers, and so forth) and a study of the several factors involved, the directors authorized publication of the Year Book each year as of September 1, beginning with the 1948 edition, and in its present form.

The board of directors voted to authorize the appointment of five representatives on an intersociety committee to co-operate with the Thomas Alva Edison Foundation, Inc., and to grant permission for the use of the Institute membership list in connection with the program of the Foundation.

ATTENDANCE

Present at the meeting were

President—B. D. Hull, Dallas, Tex. *Past President*—C. A. Powel, East Pittsburgh, Pa. *Vice-President* —J. H. Berry, Norfolk, Va.; G. W. Bower, Haddonfield, N. J.; O. E. Buckley, New York, N. Y.; R. F. Danner, Oklahoma City, Okla.; E. W. Davis, Cambridge, Mass.; I. M. Ellestad, Omaha, Nebr.; D. G. Geiger, Toronto, Ontario, Canada; T. G. LeClair, Chicago, Ill.; C. F. Terrell, Seattle, Wash. *Director* —P. L. Alger, Schenectady, N. Y.; W. L. Everitt, Urbana, Ill.; J. F. Fairman, New York, N. Y.; R. T. Henry, Buffalo, N. Y.; M. J. McHenry, Toronto, Ontario, Canada; A. C. Monteith, East Pittsburgh, Pa.; J. R. North, Jackson, Mich.; D. A. Quarles, New York, N. Y.; Elgin B. Robertson, Dallas, Tex.; Walter C. Smith, Palo Alto, Calif.; E. P. Yerkes, Philadelphia, Pa. *Secretary*—H. H. Henline, New York, N. Y.

Other matters were discussed, reference to which may be found in this or later issues of *ELECTRICAL ENGINEERING.*

Electron Tubes Provide Subject for First of AIEE Conferences

More than 280 people attended the AIEE conference on electron tubes for instrumentation and industrial use, which was held at the Benjamin Franklin Hotel, in Philadelphia, Pa., March 29–30, 1948. This was the first of a new type of national meeting—the AIEE conference—designed specifically to meet the needs of certain technical committees who wish to attract the attention of as many engineers in a certain field as possible on some of their definite projects (*EE, Feb '48, p 189*).

In this instance the AIEE subcommittee on electronic instruments sponsored the conference which stemmed out of a discussion about a year ago at which the need for improved electron tubes for industrial purposes was recognized. An extensive survey was made of the requirements for such improved tubes, and the conference was planned to present the result of this survey to all interested parties. This survey, the "Report on Electron Tube Survey of Instrument Manufacturers and Laboratories," prepared by the AIEE joint subcommittee on electronic instruments, thus became the basis of the conference. Five different sessions covering various aspects of tube improvement problems were held during the conference.

OBJECTIVES OF CONFERENCE

The first session was presided over by E. I. Green, of the Bell Telephone Laboratories, New York, N. Y., who is also chairman of the AIEE instruments and measurements committee. W. R. Clark, chairman of the conference, who is also chairman of the AIEE joint subcommittee in electronic instruments, outlined the objectives of the conference. He pointed out that the application of electron tubes to instrumentation and other industrial use was being hampered by the unreliability of tubes and the unreproducibility of characteristics from tube to tube. Up to the present time, manufacturing emphasis has been placed on reducing the cost of a tube without seriously impairing its performance. To fulfill the requirements of industry the emphasis ought to be shifted from reducing costs to improving performance. He indicated that the conference had been planned as an educational program for both the industrial tube users and tube manufacturers so that both groups would have a better understanding of each other's problems. He outlined the material which was to be presented at the five sessions.

NEED FOR IMPROVED QUALITY

Following the statement of the objectives of the conference, a group of five papers expressing the need for improved quality in electron tubes for instrumentation and industrial use were presented.

W. C. White, research laboratory, General Electric Company, Schenectady, N. Y., who has been associated with the electron tube industry since its early infancy, reviewed its progress and pointed out that industrial organizations, like individuals, change their point of view when they pass from being a manufacturer to that of becoming a user. The use of electron tubes for industrial purposes is now only in its infancy, somewhat comparable to the position of the electron tube in the radio industry 25 years ago. He pointed out that though industrial use of electron tubes does not equal the radio use, in all probability it will do so in the future.

C. T. Burke, General Radio Company, discussed the need for improved electron tube quality. He pointed out that the actual investment in the electron tube as part of an industrial instrument or control device, is an extremely small fraction of the over-all cost of the device. From a reliability standpoint industry well can afford to pay more money for electron tubes which have a greater degree of reliability and a longer life. In the instrumentation field it is extremely desirable that the characteristics of a given type tube be closely similar to other tubes of this type so that they may be used interchangeably in the same instruments. It is also important, he pointed out, that the characteristics remain reasonably constant over the life of the tube.

A. P. Upton, Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., discussed the requirements for electron tubes in aircraft control applications. He pointed out the need for reasonably stable operation on the supply voltages available in aircraft which vary from 22 to 32 volts. He noted that the loctal-type tube had a base construction which performed very much better at high altitudes than the usual type of pressed base construction. Accuracy of characteristics in electron tubes is extremely desirable when used in indicating instruments such as fuel gauges in bombers. An inaccuracy of as much as one per cent on the fuel gauge of such a bomber means an inaccuracy of 400 pounds of fuel weight and thus can become a critical matter in military aircraft operations. He indicated a need for the development of specific types of tubes for use in instruments and control functions and that these should be attacked as the basis of design rather than to attempt a compromise by making modifications of the usual type of radio tubes.

H. F. Dart, of the Westinghouse Electric Corporation, cited the industrial control manufacturers wants as regards electron tubes. He covered such items as long life, published limits on characteristics, good shelf life, a test for imminence of failure, plate current and mutual conductance which

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in Mexico City at 10:00 a.m., Wednesday, June 23, 1948, during the summer general meeting.

At this meeting the annual report of the board of directors and the reports of the committee of tellers on the ballots cast for the election of officers and for the proposed amendments to the AIEE constitution will be presented. The Lamme Medal will be presented to A. M. MacCutcheon (F '26), and awards of Institute prizes will be announced.

Such other business, if any, as properly may come before the annual meeting may be considered.

Signed H. H. HENLINE
Secretary

South Bend Engineers on Inspection Tour

Group of 230 engineers on a recent inspection tour of the Twin Branch generating plant of the Indiana and Michigan Electric Company, South Bend, Ind., in a program sponsored by the AIEE South Bend Section and the South Bend Engineers' Club

should be uniform within plus or minus 12 per cent, life and stock availability which should be at least 15 to 20 years, and improved hum and microphonic characteristics when the tube is subjected to severe vibration.

F. B. Bramhall, of the Western Union Company, described the requirements of his company regarding the use of electron tubes. He pointed out that while his company utilizes electron tubes in communication service, the requirements are quite different from those normally required in the radio industry. He mentioned that the type *48* tube, which has been used for quite a number of years by the company in a class *A* amplifier circuit, gives better performance than the more recently developed tube types. His company makes use of approximately 32 tube types and maintains approximately 150,000 tubes in operation. He, too, expressed an interest in a longer tube life.

A number of interesting points were brought out in the discussion which followed the presentation of the five papers. One of the questions asked was why the so-called depressed cathode test for determining the life of an electron tube in service still was being used and why more modern techniques were not employed in this regard. It was pointed out that though this method of test may not be completely satisfactory, most companies use the method because it permits testing tubes in service without interruption of their operation, and this is a fundamental requirement in a great many electron tube applications.

It was indicated that the utility industry also is interested in long tube life, and a tube test for imminence of failure, and they are interested especially in a tube that will deliver a reasonable power output at low plate voltages to a low impedance load.

A very important reason given for the lack of industrial tubes was the economic one. It was mentioned that the development cost of tubes is very high and may run as high as $50,000 for a single tube. In addition, the quantities of electron tubes which will be sold are relatively small and thus the cost of the individual tube is kept extremely high which discourages its general use.

On the other hand, more than once it was mentioned that the cost of tubes is secondary when compared with reliability in a great many applications. However no mention was made of how high this cost can go. The oil industry also was mentioned as one needing tubes that had long life, and tubes that can be relied upon to carry out certain control functions continuously. Here again, cost was said to be secondary as compared to reliability.

SCIENTIFIC APPARATUS MAKERS' SURVEY

J. W. Harsch, of the Leeds and Northrup Company, presented a summary of a survey conducted by the Scientific Apparatus Makers of America on the use of electron tubes in instruments. This was a limited survey of instrument manufacturers only. It has been discontinued now because of the work of the AIEE joint subcommittee on electronic instruments in conducting its much more comprehensive survey. It only was pointed out that the data obtained had not been turned over to electron tube manufacturers but had been studied by the instrument makers themselves.

AIEE JOINT SUBCOMMITTEE SURVEY

Four short papers then followed which described various aspects of the electron tube survey of instrument manufacturers and laboratories as conducted by the AIEE joint subcommittee on electronic instruments.

H. R. Meahl, of the General Electric Company, discussed the formulation and circulation of the questionnaires. E. Isbister, of the Sperry Gyroscope Company, outlined the method of summarizing replies to the questionnaire. He explained the use of the various formulas which appear in the survey report. T. B. Perkins, of the Radio Corporation of America, gave a general summary of the results of the questionnaire. He covered most of the results of the survey, leaving the unusual requests to G. N. Mahaffey of Sylvania Electric Products Inc., who discussed this phase of the results.

DISCUSSION

The discussion that followed these talks brought out a few interesting points. Automatic circuit switching was suggested as a means of providing dependability where this need is of paramount importance. Another point mentioned was that one of the greatest lacks of information with regard to electron tubes is that we do not have a knowledge of the variations in the characteristics of tubes with life. This brought up a discussion of tube life. As many factors enter into the determination of how long a tube will operate satisfactorily, the so-called "tube life" is very difficult to define exactly. Tube life will vary with type of operation such as continuous or intermittent. Operating beyond the ratings of the tube or below the ratings of the tube, also will have a marked effect on tube life. It was pointed out that in the design of a tungsten filament a rather definite life based on the rate of boiling off of the metallic filament was capable of being calculated. On the other hand, reasonably definite prediction of cathode life for the coated cathode is more of a matter of probability. There is just as much chance of a tube failing in the first thousand hours of operation as there was in the last thousand hours of operation. No satisfactory test for imminence of failure has been devised as yet.

An interesting comment was offered by a member of Bell Telephone Laboratories which indicated that in 1936, 100 tubes were made under engineering supervision by that company. A check made a few years ago revealed that 90 of the tubes still were operating satisfactorily in 1946. There was no information available on the other ten tubes because for various reasons these tubes could not be found.

A very popular comment that kept recurring during the discussion was the need for a set of "fundamental ratings" for electron tubes. It was pointed out that the material available in most handbooks on tube ratings was very good with regard to using the tubes in communication circuits. However, in industrial and instrumentation use more often than not these data were useless. Because of the wide range of application of electron tubes it was almost impossible to give ratings in a handbook that would satisfy all possible users and so it was suggested that a set of so-called "fundamental ratings" be arrived at and that these ratings be published. The complexity of this problem was brought out and recognized, and it was suggested that this topic well might be one on which the subcommittee could do some much-needed work.

The question was asked whether the survey indicated that military requirements for electron tubes differed from those of industrial users. The summarizing of the questionnaire had not been broken down to that extent which made it difficult to answer that question exactly. However, Conference Chairman Clark pointed out that it was his impression that there was not any appreciable difference between military requirements and the industrial requirements.

SECOND SESSION

In session 2 the function and aims of the joint electron tube engineering council were presented, and current development programs for obtaining improved tubes for use by other special user groups were discussed to determine the possible bearing of these programs upon each other and upon instrumentation needs.

V. M. Graham, of Sylvania Electric Products Inc., who was also chairman of the joint electron tube engineering council (JETEC) of the Radio Manufacturers Association and the National Electrical Manufacturers Association, discussed the work of JETEC. Briefly, he gave a short history of the working group and outlined its method of arriving at the information given in the JETEC data sheet. A short outline of the present organization and personnel of JETEC also was presented.

CURRENT DEVELOPMENT PROGRAMS

Five papers were presented next which dealt with the current programs of electron tube development in various fields.

C. Banks, of Aeronautical Radio Inc., discussed commercial aviation's problems in this respect. Electronic equipment is now very vital to aircraft operation and complete reliability is required today. As might be expected, physical size, reliability, and ability to withstand severe treatment are of special interest to the aviation industry.

R. L. Snyder, of the University of Pennsylvania, outlined electron tube requirements for digital computers. Here again reliability and ruggedness are of great importance. These two factors will lower initial cost a great deal and simplify construction and reduce maintenance of computers. The suggestion was made for the modification of certain tubes and also the development of new tubes to produce high current and certain types to do switching operations.

J. W. Greer, of the Bureau of Ships, outlined the Navy's development program. Ruggedizing of electron tubes is occupying much of the Navy's attention for these tubes have to operate aboard ships under conditions of severe vibration and shock.

D. Gibbons, of the Signal Corps engineering laboratories, covered the Army's development program. The Army is sponsoring a number of basic studies in the electron tube field. Investigation of filamentary alloys for performance are under way. Various types of accelerated life tests are also under investigation.

R. J. Framme, of the Air Materiel Command, discussed the Air Force's electronic problems. These problems were said to be a great deal like those of the commercial aviation industry with an added item of importance which was the requirement for large numbers of tubes. Military aircraft is going to depend more and more upon electronic controls and instruments, thus the concern about the availability of large numbers of tubes.

J. R. Wilson, of the Bell Telephone Laboratories, cited the problems of the Bell system and how they are approached. He mentioned the fact that the Bell system tried to co-ordinate its development program in such a manner that there was complete co-operation between the tube designer, circuit designers, tube manufacturer, and the user of the equipment. In this way it was possible to realize long tube life and satisfactory operation. It was appreciated that in most instances this co-ordinated program was not possible for the average electron tube manufacturing company.

A. Lederman, secretary of the panel on electron tubes of the Research and Development Board, covered the common objectives in electron tube development program. These included improving mechanical strength, reliability of tubes, and long life.

As before, these papers provoked a considerable amount of discussion. Mention was made of a secondary emission project sponsored by the Army in which an investigation was being carried on with regard to immunity to poisoning of the grid due to exposure to the cathode oxide. A suggestion was made that research be carried on on the leaking of tubes as this was believed to be a possible contributor to the shortening of tube life. With regard to the evaluation of expected tube life it was pointed out that accelerated life tests are all right but no correlation yet has been found between these and normal tests.

DINNER PROGRAM

A dinner was held at 6:30 p.m. during which Professor W. G. Dow, of the University of Michigan, who is also vice-chairman of the AIEE electronics committee, acted as toastmaster. Conference Chairman Clark was introduced, and in turn he introduced the various members of the joint subcommittee on electronic instruments who had helped to make the conference possible.

The main speaker of the evening was W. R. G. Baker, of the General Electric Company, who is chairman of the AIEE communication and science co-ordinating committee. His topic was "Manufacturing Policy With Relation to Special Tubes." This talk was the keynote for the subjects which were discussed at the third session which immediately followed the dinner.

IMPROVED TUBE CONSIDERATIONS

The after-dinner program, under the chairmanship of Professor Dow, was devoted to a discussion of design, manufacturing, and economic considerations regarding improved electron tubes for instrumentation and industrial use.

N. H. Green, of the Radio Corporation of America, treated design considerations. He outlined the various factors which go into the design of an electron tube with excellent qualities such as would be used in instrumentation and in industrial use. Much of his material was based on the experience of the Radio Corporation of America in developing the new "red line" vacuum tubes, a special series of three tube types which have been introduced recently for industrial use.

Manufacturing considerations were covered by N. L. Kiser, of the Sylvania Electric Products Inc. Among the various points that he brought out was the suggestion that a special section of a plant or a special plant be set up for the manufacture of industrial tubes, and that this operation be kept divorced completely from manufacturing radio-receiving-type tubes. Here quality would be the rule and the manufacturing tempo necessarily would be slower.

The final talk in this series discussed economic consideration and was presented by N. B. Krim of the Raytheon Manufacturing Company. The speaker pointed out the various factors which go into the cost of making and selling electron tubes. He selected a hypothetical tube and presented figures which, though not accurate in the sense that they had been proved, were nevertheless a reflection of his experience, which indicated just how much an electron tube with "super quality" would cost the user. One of the interesting points of this discussion was the fact that according to the figures and the economic considerations presented, a single manufacturer or source of supply of these high quality tubes could operate economically and make a reasonable profit. However, in some instances, if two manufacturers entered the field and acted as sources of supply both would lose money and consequently go out of business. In the case of three manufacturers acting as a source of supply, all would lose money.

In the discussion which followed the size of the market for the special purpose tubes claimed most of the attention. Mr. Krim, when asked, ventured a guess that the size of the market for special purpose tubes would run in the neighborhood of $1,000,000 to $1,500,000. He mentioned that this was purely a guess as no actual figures were available. Mr. Badger of the magazine, *Electronic Industries*, mentioned a figure of $34,000,000 which included transmitting tubes down to the smaller size special purpose tubes. This latter figure was an RMA figure for 1947.

OPEN FORUM ON SPECIFIC TUBE TYPES

The two sessions held on Tuesday were devoted to an open forum on electron tubes for instrumentation and industrial use. D. G. Fink, editor of *Electronics* magazine, and chairman of the AIEE subcommittee on electronic aids to navigation, presided over the first of these two sessions. Both sessions were devoted to a discussion of tubes on the basis of specific functional types. Each type was introduced by invited remarks of two speakers, one discussing the tube designer's or "maker's" problems and the other the circuit designer's or "user's" needs with respect to special purpose electron tubes. Then the meeting was thrown open to discussion on the particular type of tube.

The first of these two sessions (session 4) was introduced by C. W. Martel, of the Raytheon Manufacturing Company, who discussed design details such as basing, envelopes, and internal construction.

Open discussion on the various tube types then followed. To provide a quantitive base line for the discussion a set of hypothetical data sheets were prepared. These sheets gave the principal mechanical and electrical characteristics for some hypothetical tubes of the type scheduled for discussion. The selected characteristics were somewhere between those of present commercial tubes and those indicated as desirable by the instrument industry in the survey. The so-called hypothetical tubes described were proposed solely as a median starting point for conference discussion. No tube manufacturer was committed to their production or even has stated that their production is necessarily desirable. Neither the Institute nor its joint subcommittee on electronic instruments sponsors these tubes for meeting the specific needs of the instrument industry as evaluated in their survey.

D. B. Fisk of the General Electric Company (user), and C. R. Knight, of the General Electric Company (maker) began the discussion on the twin-diode-type tube. An important point brought out in the discussion that followed was the desirability of having balance in the tube plate sections of the twin diode. The discussion on the twin diode (medium mu) was led by C. C. Chambers, of the University of Pennsylvania (user) and C. M. Morris, Radio Corporation of America (maker). High-mu twin-triode considerations were covered by W. P. Wills, Brown Instrument Company (user) and C. M. Morris (maker). Finally the last tube to be discussed during this session was the pentode voltage amplifier, and W. H. Tidd, Bell Telephone Laboratories (user) and C. M. Morris (maker) led the discussion.

In the discussion of the medium-mu and high-mu twin triodes as well as the pentode voltage amplifier, C. M. Morris compared the new special "red line" RCA tubes which have been developed for industrial purposes with the hypothetical ratings on the data sheet. In most instances there was a marked similarity between the hypothetical requirements and the ratings of the "red line" tubes. From the considerable discussion about questions of tube life and its specification, balance and its specification, and maximum dissipations, it was clear that the user group did not have available all of the information needed, particularly with regard to the deviations to be expected from the published normals. It seems that without this information, the tolerance limits requested in answering the questionnaire have little meaning. The conclusion was drawn here that the AIEE committee should study the way in which data can be presented for the user. This general idea to study the manner in which tube characteristics best can be presented to the user is probably one of the most important results of the whole conference. This feeling was shared by Chairman Fink as well as by many others attending the conference.

AUDIENCE POLLED

During this session a number of interesting questions were asked and a show of hands was requested by the chairman.

1. How many in the audience who are users of tubes for instrumentation or industrial application are interested primarily in tubes that will perform well above ten megacycles?—20 persons.

2. How many are interested only in tubes that show good characteristics at frequencies below ten megacycles?—60 persons.

3. How many people feel that size, which includes socket and shield cover, is an item of major importance in their application?—35 persons.

4. How many have applications in which size of the tube including socket and shield is not of major importance?—40 persons.

Because much discussion was devoted to miniature tubes, two further questions were brought up and a show of hands again was requested.

1. How many in the audience are interested in the tubes with super quality characteristics?—40 persons.

2. How many are interested in miniaturization regardless of super quality characteristics?—10 persons.

The question of socket life came up in the discussion also. It was pointed out that miniature sockets in general have a longer life than octal sockets because of the smaller diameter pin in the tube bases. The smaller diameter pin and the lack of a glob of solder at the end of the pin did not cause excessive strain in the tube socket contact, and this materially contributed to the life of the socket.

FINAL SESSION

The final session, the second one devoted to an open forum on specific tube types was held in the afternoon. C. H. Willis, of Princeton University, who is also chairman of the AIEE electronics committee, presided over this last session.

Multigrid converters were discussed by G. B. Hoadley, of the Brooklyn Polytechnic Institute (user), R. W. Slinkman, Sylvania Electric Products, Inc. (maker), and C. E. Coon, Tung-Sol Lamp Works, Inc. (maker). The beam power tetrode was covered by E. R. Thomas, Consolidated Edison Company of New York (user), and R. L. McCormack, Raytheon Manufacturing Company (maker). The power triode was discussed by R. Feldt, DuMont Laboratories (user), and R. L. McCormack (maker). Professor A. H. Waynick of the Pennsylvania State College (user), and N. L. Kiser, Sylvania Electric Products, Inc. (maker) spoke on power rectifiers. Gaseous voltage regulators were discussed by A. J. Williams, Leeds and Northrup Company (user), and V. Ulrich, Hytron Radio and Electronics Corporation (maker). Electrometer tubes were covered by H. F. Dart, Westinghouse Electric Corporation (user), and R. W. Slinkman (maker). Finally, miscellaneous tubes were discussed by J. G. Reid, Jr., National Bureau of Standards. An open discussion followed the presentation of the talks on each of the tube types.

CONCLUSIONS AND PROPOSALS

In concluding the final session of the conference, W. R. Clark, the conference chairman, reviewed the conclusions of the conference and proposed a number of resolutions for consideration.

Long life and dependability of tubes are the most important factors. This was indicated from the various discussions at the conference. Reproducibility of characteristics between tubes is also very important as far as the instrument manufacturers and industrial users are concerned. Continuity of supply is vital and notice of withdrawal of the tube ten years before withdrawal takes place would be of valuable assistance to the users. The discussion indicated that probably two lines of tubes will be required. One will be the normal-sized industrial type of tube of which the new "red line" tubes officially announced by RCA are a good example. The other type would be quite similar in its electrical characteristics to the larger envelope tube, but it would be contained in a miniature envelope. This type of tube is of particular importance in the instrument and aircraft fields.

It would seem that the hypothetical tubes presented by the committee with the modifications suggested in the discussion, would be a good basis for the design of tubes for the immediate future for use in instruments and for other similar industrial purposes. More distant future objectives of the tube manufacturers should include long life—50,000 hours, closer tolerances, more efficient cathodes permitting lower heater currents, and a further reduction of hum, noise, and microphonics is very desirable also.

Committee recommendations as a result of this conference include the following:

1. That tube manufacturers and users consider the results of the survey plus the discussions of the conference as a basis for the design, application, and standardization of tubes for instrumentation and similar industrial purposes.

2. That more complete specifications be given on industrial tubes. In addition to minimum, average, and maximum tolerance ratings on the important electrical characteristics, information should be given on at least two points on the plate current curve, and preferably three.

3. That some specifications of change during life should be given. For example, the change in the value of an amplifier tube's transconductance during life could be specified not to exceed ten per cent of its initial value. A different specification would be required for other types of tubes.

4. That instrument people use these new tubes and use them within their ratings.

As for future activities of this committee in this particular field it was recommended that:

1. This committee continue its interest in this work of proposed hypothetical tubes, possibly setting up design objectives for additional types of tubes which are needed in the instrument and industrial field.

2. For the present this committee act as a clearing house for information relating to tube specifications covered in the survey report, and act in close co-ordination with JETEC. The committee requests that all those who have definite ideas on more complete specifications and tolerances than those given in the preliminary sheet, forward their ideas to this committee in care of AIEE headquarters in New York, N. Y.

3. Because of the interest shown in this conference, another electron tube conference of wider scope be considered for next year.

4. Further discussion with representatives of other user groups should be arranged to discuss common objectives, avoid duplication of effort, and to reduce the number of special tubes to a minimum.

PUBLICATION OF CONFERENCE DATA

In addition to the foregoing news report of the conference, brief digests of the various talks presented at the conference are scheduled for early publication in *ELECTRICAL ENGINEERING*.

The "Report on Electron Tube Survey of Instrument Manufacturers and Laboratories," prepared by the AIEE joint subcommittee on electronic instruments, the material on which much of the information discussed at the conference was based, is available at $1 to AIEE members and $2 to nonmembers.

The "Proceedings of the Conference on Electron Tubes," which will include the full text of all the talks presented as well as the discussion that took place is in preparation and soon will be available. Both publications ordered at the same time may be had at the special price of $2 to AIEE members and $4 to nonmembers. Requests should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

WORKING COMMITTEES

The various committees responsible for the success of the conference on electron tubes were divided into two groups. The conference committees under the chairmanship of W. R. Clark, with C. S. Schifreen acting as treasurer, include

Program Committee: J. G. Reid, Jr., *chairman;* C. T. Burke; G. N. Mahaffey; T. B. Perkins; E. R. Thomas; W. P. Wills.

Publication Committee: L. T. Bourland, *chairman;* C. T. Burke; H. C. Drake; R. Feldt; G. B. Hoadley; E. Isbister; G. N. Mahaffey; C. W. Martel; H. R. Meahl; T. B. Perkins; E. R. Thomas; A. H. Waynick.

Publicity Committee: W. H. Tidd, *chairman;* H. W. Berry; C. T. Burke; C. C. Chambers; D. B. Fisk; C. S. Schifreen; J. J. Slattery; C. C. Wilson.

The Philadelphia committee, under the chairmanship of A. P. Godsho, includes

Hotel Committee: S. L. Gibble, *chairman;* H. J. Talley.

Finance Committee: A C. Muir, *chairman;* J. Gammell; C. T. Pearce.

Publicity Committee: C. S. Schifreen, *chairman;* J. E. Johnson, *vice-chairman;* D. R. Boone; E. T. Davis; R. Eages; R. T. Ferris; F. F. Herrmann; E. C. Hubbard; J. E. Luckman; M. R. Ling; R. Pfair; W. E. Smith; R. E. Tarpley; C. L. Taylor.

Registration Committee: L. R. Gaty, *chairman;* H. W. Berry; F. R. Ford; H. S. Warford; R. Williams.

Hospitality Committee: W. P. Wills, *chairman;* E. F. Upton, Jr.

Analysis of Registration at Philadelphia

District	Members	Men Guests
1	21	30
2*	91	77
3	15	17
4	0	1
5	8	12
6	0	0
7	0	1
8	1	2
9	0	0
10	1	4
Totals	137	144

* District in which conference was held.

New Policy Extended for Advance Pamphlets of Papers

The new price policy for advance pamphlet copies of authors' manuscripts of technical program papers, popularly known as "preprints," (*EE, Apr '48, p 378*) has been liberalized to the extent that authors, or the organization with which the authors are affiliated, may obtain quantities of pamphlets in advance of a meeting at the member's single-copy price, provided a written order is submitted with the manuscript.

This new policy on the pricing of quantities of "preprint" pamphlets already has been placed in effect with all papers released for publication.

Great Lakes District Meeting Held in Des Moines, Iowa

Sponsored by the Iowa Section, the eighth in the series of Great Lakes District meetings was held at the Fort Des Moines Hotel in Des Moines, Iowa, April 1–3, 1948. This was the first such meeting to be held so far west in District 5, and the response was good, as the location was conveniently accessible to a membership area not heretofore directly served by District activity.

The program was arranged to extend into Saturday sessions in order to provide maximum availability to students from the engineering schools in the area. The arrangement appeared to be mutually satisfactory, and it was noted that attendance at the Saturday mornng technical sessions was at least as good as at the Thursday and Friday sessions.

Student attendance was very heavy at both Friday and Saturday sessions, the student registration accounting for approximately half the total registration. Comparative registration statistics are given in the accompanying tabulations.

TECHNICAL PROGRAM

A total of some 38 topics was presented at the seven technical sessions, including 13 formal technical program papers, 8 conference papers, 10 undergraduate student papers, and 7 graduate student papers. Many observers commented upon the rather exceptionally high quality of the student papers presented, and the high proportion of original work on new subjects or on old phases of old subjects represented in these papers. With the exception of the student technical session, which drew an attendance of 125 or more, the outstandingly popular session was the conference symposium on nucleonics which drew and held for some three hours an attendance of approximately 165.

In an interrelated series of talks, at the nucleonics session, Doctor J. B. Livingood of the Collins Radio Company, Cedar Rapids, Iowa, described and explained the operation of cyclotrons; Doctor H. C. Pollock of the General Electric Company, Schenectady, N. Y., similarly described and explained the nature and operation of the synchroton; Doctor A. Watenberg of the Argonne National Laboratories, Chicago, Ill., described and explained the various present concepts of nuclear reactors which is a general term including the atomic pile of wartime fame; radiation measurements and some of the instruments, problems, and possibilities involved were outlined by Professor D. S. Martin of the chemistry department of Iowa State College at Ames and a member of its Institute for Atomic Research. It is expected that the general subject matter of these talks will be embraced in the articles of the nuclear series currently being published in *ELECTRICAL ENGINEERING*, or will be covered in special supplemental articles.

STUDENT PAPERS

A listing of the previously mentioned student technical papers is given in the following tabulation. In general, these papers were the winners in local competitions, and their presentation at Des Moines was of the nature of a final competition for District recognition.

UNDERGRADUATE PAPERS

1. (*First prize*) "Ionization Gauge Metering Circuit," by Carl A. Hermanson, Northwestern University
2. (*Second prize*) "An Electronic Frequency Meter," by Donald O. Pederson, North Dakota Agricultural College
3. (*Third prize*) "Stabilizing a 100-Volt Power Supply," by Edwin R. Rathbun, Jr., Iowa State College
4. (*Honorable mention*) "Design of a High-Fidelity Portable Phonograph Amplifier," by Robert Leopold, University of Michigan
5. (*Honorable mention*) "The Gyroscopic Navigator," by Gene M. Amdahl, South Dakota State College
6. "The Mechanical Polar Plot of βK of a Feedback Amplifier," by Robert Grove, Illinois Institute of Technology
7. "Pearl Street—Birthplace of the Electrical Industry," by Charles Allender, University of Iowa
8. "The Suppression of Phonograph Record Noise," by Eugene R. Zobel, University of North Dakota
9. "Electronic Control of an Amplidyne," by John A. Teske, University of Notre Dame
10. "Study and Measurement of Luminaire Brightness," by Richard L. Garber, University of Wisconsin

GRADUATE PAPERS

1. (*First prize*) "The Reverse Blowout Effect," by Gary J. Himler, Illinois Institute of Technology
2. (*Second prize*) "Punched Card Machines and Routh's Criterion of Stability," by Lindon E. Saline, University of Wisconsin
3. (*Honorable mention*) "The Transient Behavior of a Small 2-Phase Induction Motor," by Arthur M. Hopkin, Northwestern University
4. (*Honorable mention*) "A Study of Parallel T R-C Networks," by C. E. Bergman, University of Illinois
5. "Electrical Analogue Computing," by M. Skinner, Michigan State College
6. "Developments in Man-Made Radio Interference," by Robert C. Walker, University of Michigan
7. "The Induction Method of Testing Rails in Track," by Philip T. Kennedy, University of Minnesota

It is expected that several of the foregoing Great Lakes District student papers will be published in forthcoming issues of *ELECTRICAL ENGINEERING*.

PRESIDENT HULL SPEAKS

President Blake D. Hull was the feature speaker of the opening general session Thursday morning. In speaking on the topic, "Ceiling Unlimited," he stated that the present and forthcoming generation of electrical engineers is confronted with an extent and diversity of rapid growth which offers great individual opportunity and challenges the very best effort and study. He discussed the interrelationship of research, basic science, and engineering applications, drawing attention to the ever closer and closer relationship between pure and applied science.

In touching upon the subject of engineering education, President Hull mentioned the seeming necessity of somehow providing more time in engineering collegiate curricula for appropriate attention "to the broader topics which challenge and stimulate thought on important subjects of nontechnical nature, as well as the fundamental technical subjects." In passing along a bit of advice to engineering students, President Hull pointed out that the rapidly growing range of technical subject matter, of which electrical engineering students must acquire a good fundamental working knowledge, is so great as to preclude in engineering courses "an adequate grounding in humanities and purely cultural subjects such as are common, for example, in the undergraduate work of legal and medical profession." He pointed out that this puts an additional challenge up to the individual electrical engineering student to supplement his formal curricula by a wide selection of extracurricular activities. President Hull urged students to "join and take an active part in church, civic, and technical organizations, on campus and off campus, to learn how to get along with people and to establish a first-hand understanding of common general human problems."

As a warning against overdilution of technical studies and activities, President Hull warned that engineers as a professional group best can serve the nation by being good engineers. He mentioned however that a good engineer is, among other things, a good citizen; and that a good citizen takes an active part in public affairs according to his personal interests and abilities.

The opening general session was presided over by R. F. Castner of the Iowa Section, executive vice-chairman of the District meeting committee. Vice-President T. G. LeClair of Chicago, in brief introductory comments, pointed out that although Iowa popularly was known as an agricultural state, it has developed in recent years to a point where about half of the income of the state now comes from widely diversified industrial establishments. Thus, he considered it quite appropriate that AIEE should recognize this situation, as it did by holding the current Great Lakes District meeting in Des Moines. The official welcome to the city of Des Moines was extended by Secretary Brade of the Des Moines Convention and Tourist Bureau.

INSPECTION TRIPS

Four interesting and instructive inspection trips were provided through the co-operation of local industries. Those interested in electric light and power generation and distribution facilities, were given a tour by the Iowa Power and Light Company through its major Des Moines property. Those interested in rubber manufacture were accommodated by the Des Moines plant of the Firestone Tire and Rubber Company, and the plant of the Lake Shore Tire and Rubber Company. Those interested in the intricate progressive electric welding of stainless steel operations involved in the building of aircraft engines were accommodated by the Solar Aircraft Company. Aside from the interest centered in the stainless-steel manufacturing processes, another item of parallel interest in the Solar plant was the 13.2-kv electric power distribution system servicing the several floors of the large factory building through the medium of nine substation units distributed throughout the plant, six transforming direct from 13.2 kv to 440 volts for power service, and three providing direct transformation for 220–110-volt lighting and auxiliary circuit. The plant engineer told visitors that Solar was able to maintain 96 per cent power factor for the plant by the use of static capacitors and synchronous motors, and that the relatively high voltage of the basic distribution system provided a very useful flexibility in accom-

modating quick relocation of heavy manufacturing equipment to meet the changes in adjusting production lines to meet product requirements.

ENTERTAINMENT

For a District meeting, there was a particularly generous array of entertainment activities for both men and women. These included an informal banquet Thursday evening, a general luncheon Thursday noon, and a Student Branch luncheon Saturday noon; and various purely social affairs including a women's tea at the Wakonda Club, and an informal dinner held on Thursday evening at the Des Moines Club expressly for women guests by the Iowa Power and Light Company. A double-feature program was presented at the informal banquet, the first part being a comparative demonstration of radio reproduction equipment and a half-hour skit burlesquing the operation of a radiobroadcasting station, under the animated direction of J. A. Green of the Collins Radio Company of Cedar Rapids, Iowa; the second feature was a talk given by Forrest W. Seymore of the Des Moines *Register* and Des Moines *Tribune*, 1942 Pulitzer prize winner for distinguished editorial writing, reflecting his observations and experiences while recently travelling through the eastern Mediterranean countries. At the general luncheon, Doctor J. F. D. Smith, dean of engineering, Iowa State College, Ames, spoke on the topic, "Industrial Research and Development," discussing some of the shortcomings and possibilities of industrial research and development work. At the student luncheon, Dean O. W. Eshbach of Northwestern Technological Institute, Evanston, Ill., gave an inspirational talk built around the topic, "The Green Pastures." The general sentiment carried away from this talk was to the effect that the greenness of one's own "pasture" depends in substantial measure upon the extent and application of one's foresight, imagination, and initiative; that the pasture on the other side of the fence is not necessarily any greener, in spite of its appearances from a distance.

MEETING COMMITTEES

The smooth functioning of the Des Moines meeting reflected the advance work done by the District meeting committee and its associated special committees. At the opening session, Vice-President LeClair took considerable pains to emphasize that whereas by custom he as AIEE vice-president was designated as chairman of the District meeting committee, it was Vice-Chairman R. F. Castner of Des Moines whose executive administration had marshalled together the various activities comprising the program. The personnel of the District meeting committee was reported as follows:

District Meeting Committee

T. G. LeClair, *chairman;* R. F. Castner, *vice-chairman;* R. E. Beam; W. L. Cassell; J. V. Gebuhr; B. C. Lueders; N. C. Pearcy; A. W. Rauth; J. D. Ryder

Other committees for the meeting, with their chairmen, were

Program Committee: J. D. Ryder, *chairman*

Finance Committee: R. F. Castner, *chairman*

Hotels and Registration Committee: J. H. O'Day, *chairman*

Trips and Transportation Committee: G. A. Corcoran, *chairman*

Publicity Committee: J. V. Gebuhr, *chairman*

Banquet Committee: K. R. Brown, *chairman*

Womens' Entertainment: Mrs. D. A. Powell, *chairman*

Student Branches Confer at Des Moines Meeting

As a part of the program of the Great Lakes District meeting held in Des Moines, Iowa, April 1–3, 1948, the committee on Student activities of the Great Lakes District held its annual business conference of Student Branch counselors and Student representatives from the various Branches, at the Fort Des Moines Hotel, Des Moines, Iowa, Saturday morning, April 3.

A substantial proportion of the meeting was devoted to the presentation and description of annual operating reports from each of the 20 AIEE Student Branches in the fifth District. Other business included the decision to hold the 1949 Great Lakes District conference on Student activities at the University of Michigan "not earlier than the latter part of April 1949."

Professor H. S. Dixon, Student Branch counselor, North Dakota State Agricultural College, Fargo, was elected to serve a term on the fifth District committee on Student activities beginning August 1, 1948, becoming the "junior member" of that committee and taking the place on the committee of its present chairman, Branch Counselor R. E. Beam of Northwestern Technological Institute, who will retire from the committee at the close of his present term as chairman, July 31, 1948. Carrying out the progression established many years ago, Professor E. W. Kane, Student Branch counselor of Marquette University, Milwaukee, Wis., will become the "senior member" of the committee, and Professor W. H. Gamble, Student Branch counselor at South Dakota State College of Agriculture and Mechanic Arts, Brookings, will become chairman of the committee, August 1, 1948. Professor Beam presided at the Des Moines meeting, and Great Lakes District Secretary N. C. Pearcy from Chicago served as secretary.

Fifth District Executive Committee Meets at Des Moines

Taking advantage of the presence at the Great Lakes District meeting in Des Moines of representatives of many of the AIEE Sections in the District, Vice-President T. G. LeClair of Chicago held a District executive committee conference meeting at the Fort Des Moines Hotel in Des Moines, Iowa, Friday morning, April 2, 1948. Mr. LeClair presided, and District Secretary N. C. Pearcy kept the records.

The minutes of the preceding meeting of the District executive committee were approved as previously circulated, and other routine business was disposed of. There was considerable, although inconclusive, discussion as to the relationship to be worked out between Great Lakes District meetings and the newly established AIEE Midwest general meeting. It seemed to be the informal consensus that the District meetings should continue to be held, perhaps about every second year, and so located as to supplement rather than conflict with the Midwest general meeting. Also, there was an informal consensus that in general a spring meeting is more advantageous for the District than a fall meeting. Thus it seems probable that the next Great Lakes District meeting may be held sometime in the spring of 1950, at a date and location to be determined later in accordance with the wishes of the various Sections interested in sponsoring such a meeting.

Analysis of Registration at Des Moines Iowa

Classification	Iowa Section	District 5*	Other Districts	Totals
Members	36	44	5	85
Students	47	56	0	103
Men guests	108	29	16	153
Women guests	10	6	0	16
Totals	201	135	21	357

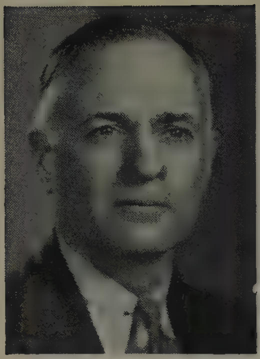
* Outside Iowa Section.

Comparison of Great Lakes District Meeting Attendance

1948	April 1–3	Des Moines, Iowa	357
1946	October 9–11	Indianapolis, Ind.	298
1939	September 27–29	Minneapolis, Minn.	230
1935	October 24–25	West Lafayette, Ind.	481
1932	March 14–16	Milwaukee, Wis.	552
1929	December 2–4	Chicago, Ill.	600
1927	November 28–30	Chicago, Ill.	900
1926	May 6–7	Madison, Wis.	180

PERSONAL

Mark Eldredge (A '14, F '33) chief, electrical equipment section, surplus war properties division, Defense Plant Corporation, Washington, D. C., has been appointed chief of the power and fuel requirement section, power and utilities division, Munitions Board. His primary responsibility will be to direct a committee of power experts and specialists representing all three branches of the Armed Forces relative to military needs for electric power in camps and stations and in manufacturing plants owned and operated by the military establishment. A graduate of Worcester Polytechnic Institute with a degree of bachelor of science in electrical engineering in 1906, he later took special courses in business and accounting at Columbia University. Following a varied career which included service in the United States Army in World War I and the construction and operation of power systems in India, he became assistant engineer for Electric Bond and Share Company, New York, N. Y., in 1922. Two years later he became electrical engineer for the Memphis (Tenn.) Power and Light Company and chief engineer in the following year. Mr. Eldredge was called to Washington in 1940 to assist in the industrial part of the national defense program, and was in charge



Mark Eldredge

M. F. Skinker

J. A. Hutcheson

H. A. Leedy

L. M. Moore

of power supplies for various basic war industries. Since 1944 he had been on the surplus property board and the various agencies which replaced it. His AIEE activities have been extensive; he was vice-president representing the Southern District (number 4) 1935–37, a member of the board of directors 1939–43, and served most recently on the committees on constitution and bylaws 1941–47 (chairman 1944–46) and planning and co-ordination 1944–46. Organizer and first chairman of the AIEE Memphis Section, he also is a member of the American Society of Mechanical Engineers and the Electrochemical Society.

J. A. Hutcheson (M '44) associate director of research, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed director of the laboratories. Born on January 21, 1905 in, Park River, N. Dak., Doctor Hutcheson received the degree of bachelor of science in electrical engineering from the University of North Dakota in 1926 and the honorary degree of doctor of science in 1944. He first was employed by the Westinghouse Electric and Manufacturing Company in 1926 in the radio engineering department, and successively held the positions of junior engineer, design engineer, section engineer, and manager of the radio engineering department. During the war he supervised the engineering of all the radio communication and radar equipment produced by the company for the Armed Forces. In 1943 he was appointed associate director of the laboratories, a position in which he has directed the formulation of plans for atomic energy development. A member of the AIEE research committee from 1945 to 1947, he is a member of the Institute of Radio Engineers and Sigma Xi.

L. M. Moore (M '40, F '45) principal engineer, technical standards division, Rural Electrification Administration, Washington, D. C., has joined the firm of Louis T. Klauder and Associates, consulting engineers, Philadelphia, Pa., as an electrical engineer. Born in Wheatland, Wyo., December 28, 1903, he attended Staunton Military Academy and completed his studies in electrical engineering at the University of Alabama in 1927. From 1923 to 1936 he was employed by the Alabama Power Company, advancing from draftsman to district superintendent at Selma, where he directed design, contruction, and operation of electric, gas, and street railway systems. His next position was with the Rural Electrification Administration in Washington and in St. Louis, Mo., from 1936 to 1948, advancing progressively from associate engineer to principal engineer, technical standards division. In this latter position, Mr. Moore co-operated with manufacturers in the development and improvement of rural power line protective equipment and was REA representative in the development of rural telephone service over rural power lines at carrier frequencies. He is the holder of two patents and has been author and coauthor of numerous technical papers. Mr. Moore served on the AIEE power transmission and distribution committee from 1942 to 1946 and on the communication committee during the year 1945–46.

H. A. Leedy (M '46) chairman of physics research at Armour Research Foundation of Illinois Institute of Technology, Chicago, has been named acting director of the foundation. Born April 15, 1910, in Fremont, Ohio, Doctor Leedy received his bachelor of arts degree in physics at North Central College in 1933. He obtained his master's and doctor's degrees in physics at the University of Illinois in 1935 and 1938, respectively. From 1938 to 1944 he was a physicist in acoustics at Armour Research Foundation and since 1944 has been chairman of physics research. During the war he was active in the foundation research program on magnetic wire sound recording and in charge of several projects for the United States Navy, Office of Scientific Research and Development, and industrial research programs. His society memberships include the Institute of Radio Engineers, the American Physical Society, Acoustical Society of America, and Sigma Xi. Currently he is serving as program chairman of the 1948 National Electronics Conference.

J. W. Campbell (M '39) outside plant engineer, American Telephone and Telegraph Company, New York, N. Y., is on leave of absence from the company to fulfill an assignment in Germany for the American Military Government, at the request of the Department of the Army. He will be stationed in Berlin. A graduate in 1906 of the University of Michigan, Mr. Campbell has had a long career with the telephone company, starting with the New York and New Jersey Telephone Company of which he became district plant engineer in 1909. He was transferred to American Telephone and Telegraph Company in 1916, and was promoted to his present position in 1939. **C. G. Sinclair, Jr.** (M '46) telephone engineer, American Telephone and Telegraph Company, has been appointed outside plant engineer of the engineering division to succeed Mr. Campbell. A graduate of Columbia University, he started his telephone career in 1913 in New Jersey.

M. F. Skinker (A '22, F '34) who has been assistant to the chief engineer, Ansco Division, General Aniline and Film Corporation, Binghamton, N. Y., has been named manager of the personnel administration department. A native of Denver, Colo., with the degrees of bachelor of science (1919) and of master of science (1921) from the University of Colorado, he received the degree of doctor of philosophy from Oxford University in 1924 as a Rhodes scholar. Following his return to the United States, he became research engineer for the Brooklyn (N. Y.) Edison Company and served as assistant director of research from 1924 to 1937. In the latter year he was made associate director of research, then in 1942 he became chief development engineer in the development department of the Federal Telephone and Telegraph Company, which position he resigned in 1945 to do independent consulting work. A former member of the AIEE board of examiners (1944–46), he has served on the committees on electrochemistry and electrometallurgy (1936–46; chairman, 1938–40), technical program (1938–40), and basic sciences (1942–46). He is a member of the American Society for Testing Materials and the American Physical Society.

W. A. Coates (A '14, F '26) manager of home sales of the Metropolitan-Vickers Electrical Company, Manchester, England, has been appointed to the board of the company. His early career following training at Finsbury Technical College included being chief engineer of the Ferranti Electrical Company of Canada during the period from 1912 to 1915. In 1919 he became chief engineer of the Metropolitan-Vickers switchgear department, where he was responsible for the development of the company's first metal-clad and high-voltage outdoor switchgear. Subsequently he supervised the work of the company for the Central Electricity Board during the initial stages of design and construction of the grid network. He has made several contributions to technical literature, particularly on switchgear. Mr. Coates is also a member of the Institution of Electrical Engineers.

E. S. Banghart (A '25) who has been representative, Allis-Chalmers Manufacturing Company, New York, N. Y., has been appointed manager for the New York district of the Pennsylvania Transformer Company. Mr. Banghart had been with the Allis-Chalmers company in New York and Washington, D. C., and previously had been New York manager of the Pittsburgh Transformer Company. Prior to that, he was associated with the United Electric Light and Power Company and the New York Edison Company, both in New York.

D. R. E. Barnaby (A '46) has been appointed assistant to the president of Canadian Line Materials, Ltd., Toronto, Ontario, Canada. A 1938 graduate of the Massachusetts Institute of Technology with a degree of bachelor of science in electrical engineering, he served two years as design engineer for TelAutograph Corporation, New York, N. Y., and in 1941 joined the staff of the Central Ohio Light and Power Company, western division, Findlay, Ohio. Later he was division operating engineer at Wooster, Ohio, and also for a time was with the Colorado Central Power Company, Englewood. During World War II he served three years as an officer in the United States Navy and was awarded the Bronze Star medal for service on the *U.S.S. Franklin*. He had returned to the Central Ohio Light and Power Company at Findlay prior to accepting his new position.

E. S. Fields (A '20, F '29) vice-president, Cincinnati (Ohio) Gas and Electric Company, has been named general manager, and will continue to serve as vice-president and also as a member of the board of directors. He first was employed by the company while he was a co-operative student at the University of Cincinnati. In 1929 he was named manager of the electric department and in 1943 became vice-president; two years later he became a director. He has served as a vice-president of the AIEE (1945–47) representing the Middle Eastern District (number 2), was chairman of the AIEE membership committee 1933–37, and was a member of the committees on code of principles of professional conduct and on industrial power applications from 1945 to 1947.

D. L. Herr (M'47) assistant to vice-president in charge of engineering, Control Instrument Company, Brooklyn, N. Y., has become associated with the engineering department of Allen-Bradley Company, Milwaukee, Wis., to develop servomechanisms for machine tool and other motor control. Mr. Herr, a graduate of the University of Pennsylvania, was a fellow of the Coffin foundation of the General Electric Company and for his master's degree worked on the problems of oscillations in nonlinear systems, using the differential analyzer. He has served as a lieutenant commander in the United States Navy and has written extensively for technical and scientific publications, being coauthor of a recent AIEE paper; his society memberships include the Institute of Radio Engineers, American Physical Society, American Mathematical Society, Sigma Xi, and Tau Beta Pi.

J. E. Hobson (A '36, M '41) has resigned as director of Armour Research Foundation of the Illinois Institute of Technology, Chicago, to become executive director of Stanford Research Institute, Stanford University, Palo Alto, Calif., an independent nonprofit organization which serves the entire western area. He was director of the department of electrical engineering at Illinois Institute of Technology from 1941 to 1944, when he was appointed director of the Armour Research Foundation and a member of the foundation's board of trustees. A biographical sketch of Doctor Hobson appeared recently in *ELECTRICAL ENGINEERING* (*Oct '47, p 1028*) in connection with his appointment as chairman of the AIEE committee on registration of engineers. He currently is serving on the AIEE committees on research and electronics and previously has served on several others.

T. J. Little (M '45) formerly manager of the transmission engineering department of the Anaconda Wire and Cable Company, New York, N. Y., has been appointed eastern sales manager with offices in New York of the Pyle-National Company, Chicago, Ill. Mr. Little has been a member of the sales organization of Anaconda Wire and Cable Company since 1925. During the recent war period he served for two years with the New York Ordnance District, receiving the United States Army award for meritorious civilian service. He also has served in Germany as chief of the nonferrous metal section of the Office of Military Government, and in 1946 was United States delegate to the International Conference on Large High Tension Systems (CIGRE) in Paris, France.

H. C. Blackwell (A '09) who has been serving as the chairman of the board of directors of Cincinnati (Ohio) Gas and Electric Company since his retirement as the president of the company in 1945, has resigned as chairman of the board and as director of the company. Starting his career in the public utility field as an engineer with the People's Light Company of Davenport, Iowa, in 1906, he advanced to vice-president and general manager, and in 1917 assumed the same title with the Kansas City (Kans.) Power and Light Company and in 1924 with the Cincinnati utility. Mr. Blackwell is a past president of the association of Edison Illuminating Companies.

H. N. Blackmon (M '32) has been appointed managing editor of *Electrical World*, New York, N. Y., after having been associated with *Product Engineering* since 1945, first as electrical editor and then as managing editor. Both are published by the McGraw-Hill Publishing Company. Following graduation from Georgia Institute of Technology in 1925, Mr. Blackmon was employed by the Westinghouse Electric Corporation, and after several years as an engineer in the switchboard and general engineering departments was appointed technical editor in the technical press bureau of the publicity department. Subsequently he became manager of the editorial service of the public relations department in East Pittsburgh, Pa. He is a member of the American Society of Mechanical Engineers, the Institute of Radio Engineers, and the Instrument Society of America.

D. J. Evans (A '39) has joined Branson Instruments, Inc., Danbury, Conn., as chief engineer. After graduating from the University of Kansas with a bachelor of science degree in electrical engineering in 1938, Mr. Evans was connected with the engineering department of Phillips Petroleum Company, Bartlesville, Okla., from 1939 to 1948. He served in the United States Navy as avaiation radar officer for three years while on military leave from the company.

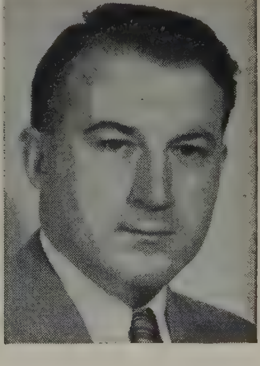
D. C. Luce (A '36, M '36) general manager, electric department, Public Service Electric and Gas Company, Newark, N. J., has been elected vice-president in charge of electric operation. He started with the company in 1924 as a cadet engineer following graduation from Lehigh University and was made

E. S. Banghart

D. R. E. Barnaby

E. S. Fields

W. A. Coates



D. L. Herr

chief engineer at Kearney generating station in 1935. The following year Mr. Luce was promoted to general superintendent of electric generation, and six years later became general manager of the electric department.

W. F. Tait, Jr. (A '27, M '45) assistant general manager, electric operating department, has been appointed general manager of the electric department. A graduate of Marietta College and Lehigh University, he started with the company as a cadet engineer in 1922 and was promoted to assistant general superintendent of electric distribution in 1938.

L. E. Bogen (A '99, F '12) sales engineer, electrical department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has retired. He was born April 9, 1872, at Cincinnati, Ohio, and received the degrees of civil engineer in 1894 and of master of science in electrical engineering in 1898 from the University of Cincinnati. In 1901 he was engaged by the Bullock Electric Manufacturing Company of Cincinnati, where he designed both a-c and d-c machinery covering a wide range of capacities. In 1903 he took charge of electrical estimating engineering and continued in this same work when the Bullock company was absorbed by the Allis-Chalmers company. In 1910 he became chief estimating engineer, and in recent years has concentrated on water wheel generators and synchronous condensers.

Bernard Lester (A '06, M '13) assistant, headquarters, industrial sales department, Westinghouse Electric Corporation, New York, N. Y., has retired, and is opening a consultation service in the sale and distribution of machinery and equipment. He was born in England on November 23, 1881, and was graduated from Haverford College. He joined the Westinghouse company in 1905, and held various positions as commercial engineer, manager of the small motor division, assistant industrial sales manager, manager of the resale department, and special representative. A pioneer in the training of industrial salesmen, he is the author of several books in that field. Mr. Lester is a member of the American Society of Mechanical Engineers and the American Society for Engineering Education.

E. O. Shreve (A '06) vice-president, General Electric Company, New York, N. Y., and president of the United States Chamber of Commerce, has received the James H. McGraw Award manufacturers medal for 1947 in recognition of his contribution to the electrical manufacturing industry's welfare and progress through unselfish and vigorous personal effort in resolving conflicts of divided interests into common industry objectives, and his leadership and inspiration in directing his industry toward broad and industry-wide goals. A native of Mapleton, Iowa, where he was born October 31, 1881, Mr. Shreve entered the employ of the General Electric Company in 1904. He has been active in the National Electrical Manufacturers Association, serving four terms as vice-president and as president from 1940 to 1941.

L. W. Chubb (A '09, F '21) is retiring from active direction of the research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.; he has been named director emeritus and will continue to serve in an advisory capacity. Doctor Chubb, who has been with the Westinghouse company since 1905 is chairman of the AIEE nucleonics committee for 1947–48. A biographical sketch of Doctor Chubb appeared in *ELECTRICAL ENGINEERING* for October 1947, page 1026, in connection with that appointment. The winner of the 1946 John Fritz medal, he was active during World War II in the development of jet propulsion, radar equipment, torpedoes, fire control, and high temperature alloys. He has been extremely active in AIEE committee work, and in addition to his current appointment is AIEE representative on the Engineering Foundation Board.

D. A. Quarles (A '23, F '41) director of apparatus development, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected a director of the Citizens National Bank, Englewood, N. J. Mr. Quarles, formerly mayor of Englewood, is chairman of the AIEE finance committee.

M. A. Lipton (M '46) Coles Signal Laboratory, Long Branch, N. J., has been cited by Major General S. B. Akin, Chief Signal Officer, for "outstanding performance of duties as electrical engineer, Fort Monmouth, N. J., from 8 January 1943 to 28 July 1947." Mr. Lipton has been associated with the Army installation for $7^1/_2$ years, and was concerned particularly with the design of Signal Corps field wires and cables.

E. H. Pollacek (A '45) formerly with Federal Telephone and Radio Corporation, Newark, N. J., has been appointed advertising and sales manager for the Power Equipment Company, Detroit, Mich., manufacturers of rectifier equipment. He will be stationed in Detroit.

D. W. Pugsley (A '36) formerly section leader for television receivers, General Electric Company, Bridgeport, Conn., has been named designing engineer with responsibility for the technical design of television receivers. He recently received honorable mention for 1944 in the Eta Kappa Nu recognition award (*EE, Feb '47, p 196*).

C. H. Weaver (A '37) marine and aviation sales manager, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named transportation manager. A native of Philadelphia, Pa., he is a graduate of the University of Pennsylvania and joined the Westinghouse graduate student course in 1936. After four years in the generator sales department he was transferred to the marine section of the industrial department, and in 1943 was made manager of the newly formed marine department, which took over aviation section activities also in 1945.

A. F. Rolf (A '03) former manager, New York (N. Y.) district, Allis-Chalmers Manufacturing Company, has retired. Mr. Rolf joined the Bullock Electric Manufacturing Company, Cincinnati, Ohio, in 1899, shortly after his graduation from Purdue University. In 1903 he entered the company's New York office and remained there when Allis-Chalmers took over Bullock the following year. In 1919 he became district office manager and served in that capacity until 1945, when he asked to be relieved. He served on the AIEE general power applications committee 1924–25.

C. P. Robinson (A '27, M '39) chief engineer, synchronous division, Ideal Electric and Manufacturing Company, Mansfield, Ohio, has been appointed to the newly created post of chief engineer of the company. Mr. Robinson, who has been with the company for the past 23 years, now has charge of all electrical and mechanical engineering operations, which includes the control division, factory test, and quality control. A native of Walton, N. Y., where he was born November 26, 1903, he is a graduate of Union College.

C. E. Stryker (A '21, F '35) recently president and general manager, Adel Precision Products Corporation, Burbank, Calif., has been elected president of Maysteel Products, Inc., Milwaukee, Wis. A graduate of Armour Institute of Technology where he received the degree of bachelor of science in 1917 and that of electrical engineer in 1924, he had been vice-president and assistant to the president of Nordberg Manufacturing Company, Milwaukee, immediately prior to his association with the Adel company. Mr. Stryker's society memberships include the Society of Automotive Engineers, The American Society of Naval Engineers, the Newcomen Society, and Eta Kappa Nu.

A. H. Frampton (A '21, F '45) who has been assistant chief electrical engineer, electrical engineering department, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been made director of engineering, engineering division. He is chairman of the AIEE power generation committee, of which he has been a member since 1942. A biological sketch of Mr. Frampton appeared in *ELECTRICAL ENGINEERING* for November 1947, page 1145, in connection with his appointment as chairman.

F. E. Wiatt (A '46) assistant supervisor, power division, Cincinnati (Ohio) Gas and Electric Company, has been appointed assistant manager of the electric sales department.

T. R. Wieseman (A '44) chief executive engineer, the Louis Allis Company, Milwaukee, Wis., has been elected vice-president in charge of engineering. He was born on May 4, 1900, at Milwaukee and studied engineering at the University of Wisconsin. He has been with the company for 22 years, becoming chief executive engineer in 1943.

J. T. Barron (A '07, F '27) vice-president in charge of electric operation, has been elected vice-president in charge of combined opera-

tions, Public Service Corporation of New Jersey, and to the same posts in Public Service Electric and Gas Company and Public Service transportation companies.

J. J. Mangan (A '44) has been appointed district engineer for the Upper Columbia District of the Bonneville Power Administration, with headquarters in Spokane, Wash. A graduate of the University of Minnesota, he has been serving with the Bonneville staff at Portland, Oreg., and formerly was district engineer at Eugene, Oreg.

W. F. Gray (A '38, M '44) formerly with the electrical engineering department, Massachusetts Institute of Technology, Cambridge, is now a member of the electrical engineering faculty at the University of Alabama, University, and never has been associated with Toole-Woodward Engineering Company as erroneously reported in *ELECTRICAL ENGINEERING* for March 1948, page 300. Also, he is a graduate of Texas Technological College and of Texas Agricultural and Mechanical College, not of Georgia School of Technology.

OBITUARY • • • • • •

Frank Wilmer Watts (A '24, M '37, F '45) sales manager of the Hart Manufacturing Company, Hartford, Conn., and formerly vice-president in charge of sales, Connecticut Telephone and Electric Division, Great American Industries, Inc., Meriden, Conn., died recently. He was born at Lockport, N. Y., April 5, 1886, and received his technical education at the Baltimore Polytechnic Institute and the Bliss Electrical School. His early employers included the New York (N. Y.) Edison Company, Chesapeake and Potomac Telephone Company, Washington, D. C., and the Westinghouse Electric and Manufacturing Company. During the period from 1907 to 1914 he served as general superintendent of the Consumers Electric Light and Power Company, Hazelton, Pa., Harwood Electric Company, Harwood, Pa., and McAdoo Electric Company, McAdoo, Pa. (all now Pennsylvania Power and Light Company), then organized and became president of the Watts Company, Philadelphia, Pa., for specialization in the sale of chain and belt type conveyors. During the years 1925–28 he was vice-president and general manager of the Modernola Company, radio manufacturers in Johnstown, Pa., then became eastern sales manager for Alden Manufacturing Company, Springfield, Mass. Mr. Watts was associated with the Condenser Corporation of America, Jersey City, N. J., 1930–33, and with the Edison Splitdorf Corporation, West Orange, N. J., in 1934 before becoming vice-president of the United Electric Controls Corporation, Hoboken, N. J., in 1935. During 1939–1940 he was associated with the Sprague Electric Company at North Adams, Mass., in the development of high-voltage pole-type capacitors and in 1941 joined the Connecticut Telephone and Electric Corporation where he was engaged particularly in the development of sound power telephones for military use in extreme cold. In 1944 the company became part of Great American Industries, Inc., and Mr. Watts was selected as vice-president. He had resigned a year ago to join the Hart Manufacturing Company. Mr. Watts previously had been an AIEE Associate from 1905 to 1914.

William John Manion (A '33) supply practices engineer, American Telephone and Telegraph Company, New York, N. Y., died on February 18, 1948. He was born on January 28, 1894, at St. Louis, Mo., and attended Washington University before entering the employ of the Southwestern Bell Telephone Company in 1914 as a draftsman, where he held several positions before becoming division plant engineer, Tulsa, Okla., in 1920 and plant engineer for Oklahoma two years later. In 1924 he was plant engineer for Missouri and Oklahoma, becoming general appraisal engineer two years later. He was transferred to the supply practices section of the plant division of American Telephone and Telegraph Company, New York, in 1928, and was made head of that section in 1939. Mr. Manion previously had been an AIEE Associate from 1925 to 1926.

Allen Bassett (A '23) treasurer, Euclid Crane and Hoist Company, Euclid, Ohio, died in November 1947 according to word recently received at Institute headquarters. He was born on March 3, 1873, at Rockford, Ill., and at the age of 14 actively was helping with an experimental electric car in Cleveland, Ohio. Following two years of college work, he was engaged in testing for the Brush Electric Company in 1895 and the following year became the superintendent of a power plant at Black River Falls, Wis. This was followed by a period of various positions in power and manufacturing plants in Crestline, Ohio; Santa Barbara, Calif.; Bedford, Ohio; and Savannah, Ga. He became associated with the Euclid Crane and Hoist Company in 1917 and was its treasurer for 27 years.

Robert Leonard Rockwell (A '13, M '22) consulting engineer, Winslow, Wash., died February 11, 1948. He was born at Peabody, Kans., December 16, 1886, and first engaged in electrical work on his own account at Baker City, Oreg., in 1905. In 1907 he became superintendent of Ontario Light and Water Company, which later was taken over by the Idaho-Oregon Light and Power Company. Resigning in 1910, and following several short periods of employment, he became head of the department of electrical engineering of Seattle (Wash.) Engineering School, Inc., a position which he held until he formed a partnership with a consulting engineer in 1917. Following dissolution of the partnership, Mr. Rockwell continued as a consultant in Seattle. He was a member of the American Society of Mechanical Engineers, and was active in the formation of the Puget Sound Engineering Council.

Allan Frank Martin (A '36) electrical engineer, engineering department, Bausch and Lomb Optical Company, Rochester, N. Y., died March 2, 1948. He was a native of Rochester, where he was born on February 6, 1890. He had been with the optical company continuously since 1913 except for a period of service in the United States Army in 1918–19. Upon his return to the company in 1919 he was engaged in experimental and design work on light projection equipment and accessories, temperature control equipment, and centrifugal apparatus. In more recent years he had concentrated on electrical problems, including the specification control and testing of all purchased electrical material. Mr. Martin was chairman of the AIEE Rochester Section at the time of his death, previously having served as treasurer, vice-chairman and secretary, and as a member of the executive committee.

Herbert L. Rawlins (A '30, M '41) manager of protective devices engineering in the switchgear and control division, Westinghouse Electric Corporation, East Pittsburgh, Pa., died February 17, 1948. Born at DuQuoin, Ill., January 4, 1901, he was graduated from Ohio State University in 1926 with a bachelor's degree in electrical engineering, and the following year received the degree of master of science. He first was employed by the Westinghouse company in 1926 in a student training course, and he returned to the company the following year when he was engaged in the development of fuses and disconnecting switches. Mr. Rawlins was made section manager in charge of this work in 1936, and in 1943 became manager of protective devices engineering including the responsibility for the development of fuses, disconnecting switches, small air circuit breakers, network protectors, lightning arresters, and capacitors. He was the author of a number of technical papers on fuses and circuit breakers, and had received many patents. He was coauthor of a paper presented at the AIEE 1947 summer general meeting.

Edward Arthur Hancock (M '38) district manager, industrial division, General Electric Company, Boston, Mass., died February 26, 1948. Born in Brooklyn, N. Y., on June 27, 1889, he studied electrical engineering at Pratt Institute, graduating with the class of 1912. He then entered the employ of the General Electric Company at Schenectady, N. Y., and two years later was assigned to the industrial control department. From 1916 until 1932 he was industrial control specialist in the New England district of the company with general engineering supervision over all installations in New England employing industrial control. He then was made assistant to the district manager, and in 1935 Mr. Hancock was made district manager, industrial department, in charge of all sales to industry in New England. Mr. Hancock previously had been an AIEE Associate from 1918 to 1927.

Henry H. Buell (A '11, M '33) superintendent, northern area, Pacific Gas and Electric Company, Sacramento, Calif., died January 12, 1948. He was born May 12, 1886, in Stockton, Calif., and received a bachelor of arts degree at Stanford University with the

class of 1909. He then became a student engineer with the Westinghouse Electric and Manufacturing Company in Pittsburgh, Pa., followed by a year of work for the United States Government in the Panama Canal Zone. From 1911 to 1920 he was employed by the Pacific Gas and Electric Company at San Jose, Calif., rising to the position of assistant superintendent. For the next two years he was electrical engineer with the Bureau of Standards, Washington, D. C., then returned to Pacific Gas and Electric Company at San Jose as superintendent of electric distribution, a position which he held until his transfer to Sacramento in 1945.

MEMBERSHIP • • • •

Recommended for Transfer

The board of examiners, at its meeting of March 18, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Bagnall, V. B., div. plant supt., long lines dept., American Tel. & Tel. Co., Washington, D. C.
Belknap, J. H., chairman, div. of engg; elec. engg. dept., University of Rochester, Rochester, N. Y.
Brown, G. H., research section head, RCA Labs., Princeton, N. J.
Dow, W. G., prof. of elec. engg. Univ. of Michigan, Ann Arbor, Mich.
Kohlhaas, H. T., asst. vice-pres. I. T. & T.; editor Electrical Communication; Reference Data for Radio Engineers, New York, N. Y.

5 to grade of Fellow

To Grade of Member

Barnes, E. C., elec. design engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Barnette, N. H., head, dept. of engg. & mathematics, Univ. of Tennessee Junior College, Martin, Tenn.
Berkshire, W. T., retired elec. designing engr., General Elec. Co., Arlington, Va.
Brenner, W. C., design engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Buechler, L. W., special project engr., Bureau of Ships, Navy Dept., Washington, D. C.
Caperton, H. O., engr. P-5, power contract specialist, Bureau of Reclamation, Washington, D. C.
Cave, J. S., Jr., district plant engr., Ohio Bell Tel. Co., Columbus, Ohio
Deane, J., commander, Royal Canadian Navy, Ottawa, Can.
Diamond, H., patent attorney, Westinghouse Elec. Corp., East Pittsburgh, Pa.
Dye, L. E., supt. electrical equipment, Los Angeles Transit Lines, Los Angeles, Calif.
Edmunds, W. H., technical asst., I-T-E Circuit Breaker Co., Phila., Pa.
Elliott, G., circuit engr., Stromberg-Carlson Co., Rochester, N. Y.
Farace, S. H., senior engr., Philadelphia Elec. Co., Phila., Pa.
Fields, C. V., design & dev. engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Franklin, R. J., chief engr., Raub-Australian Goldmining Co., Ltd., Raub, Pahang, Malaya
Frost, L. E., research electrical engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Ganther, C. E., supt. of elec. operations, The Cleveland Elec. Illuminating Co., Cleveland, Ohio
Gealt, A. E., quality control engr., The Brown Instrument Co., Phila., Pa.
Goldfarb, M. N., elec. engr., Public Service Comm., Charleston, W. Va.
Hahn, E. R., elec. engr. P-4, Bureau of Ships, Washington, D. C.
Hetherington, W. L., engr., Packard Elec. Co. Ltd., St. Catharines, Ont., Can.
Jones, R. L., inventory & costs engr., Southwestern Bell Tel Co., Oklahoma City, Okla.
Kenline, G. B., design engr., San Diego Gas & Elec. Co., San Diego, Calif.
Linders, J. R., supervising engr., protective relay div., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Litman, B., student, Columbia Univ., New York, N. Y.
Marcroft, H. C., test engr., Pennsylvania Water & Pr. Co., Baltimore, Md.
McKnight, M. N., principal engr., (marine), Navy Dept., Washington, D. C.
Monk, N., member of technical staff, Bell Tel. Labs., Inc., New York, N. Y.
Morris, E. H., chief engr., Public Serv. Comm. of West Virginia, Charleston, W. Va.
Nelson, L. N., design engr., General Elec. Co., Ft. Wayne, Ind.
Nesbit, D. E., project engr., Duquesne Lt. Co., Pittsburgh, Pa.
Paulsen, W. E., genl. shops supt., Public Service Co. of Northern Illinois, Chicago, Ill.
Pharis W. W., engineer, Stromberg-Carlson Co., Rochester, N. Y.
Radford, W. H., assoc. prof. electrical communications, Massachusetts Inst. of Technology, Cambridge, Mass.
Reveal, P. A., supervisor technical operations, WOR Program Service, Inc., New York, N. Y.
Robertson, A. W., chairman of board, Westinghouse Elec. Corp., Pittsburgh, Pa.
Rouge, F. K., engrg. vice pres., Electric Products Co., Cleveland, Ohio
Rupar, A. B., vice pres., secy., genl. mgr., Elkland Electric Co., Inc., Elkland, Pa.
Sanborn, C. A., asst. genl. mgr., Tech. Laboratories, Inc., Jersey City, N. J.
Shilcock, A. E., engr-in-chg, Cable & Wireless, Ltd., Zanzibar, Africa
Skoog, R. K., aeronautical research scientist IV., Natl. Adv. Comm. for Aeronautics, Cleveland, Ohio
Sprowl, P. R., project engr., Westinghouse Elec. Corp., Sharon, Pa.
Squires, R. B., switchgear engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Starr, A. B., Jr., elec. engr., Naval Air Station, San Diego, Calif.
Stong, K. K., development engr., Allen-Bradley Co., Milwaukee, Wis.
Strong, R. T., San Diego mgr., Westinghouse Elec. Corp., San Diego, Calif.
Sylvanus, E. C., consulting elec. engr., Canoga Park, Calif.
Terrant, F. R., elec. engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Tompkins, J., asst. elec. supt., Aluminum Co. of America, Massena, N. Y.
VonEiff, H. A., interconnection engr., Pennsylvania Water & Power Co., Baltimore, Md.
Wagner, J. L., mgr. of electrical lab., International Business Machines Corp., Endicott, N. Y.
Wagner, R. B., traffic engr.-dial, Chesapeake & Potomac Tel. Co., Washington, D. C.
Watchorn, C. W., efficiency engr., Pennsylvania Water & Power Co., Baltimore, Md.
Weil, A. F., maintenance engr., Tuttle & Kift, Inc., Chicago, Ill.
Wilde, S. F. M., sr. asst. engr., County of London Elec. Supply Co. Ltd., London, England

55 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before May 21, 1948, or July 21, 1948, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Brunetti, C., Natl. Bureau of Standards, Washington, D. C.
Young, L. C., Naval Research Lab., Washington, D. C.
2 to grade of Fellow

To Grade of Member

Anderson, E. L., Bethlehem Steel Co., Johnstown, Pa.
Anton, N. G., Amperex Electronic Corp., Brooklyn, N. Y.
Benedict, N. V., Inland Steel Co., East Chicago, Ind.
Bennett, C. E., Brown Engg. Co., Des Moines, Iowa.
Bradford, A. O., American Smelting & Refining Co., Chihauhua, Chihauhua, Mexico.
Crane, H. C., Turnbull Elevator Co., Ltd., Toronto, Ontario, Canada
Dinger, H. E., Naval Research Lab., Washington, D. C.
Dirkes, R. F., Western Union Tel. Co., New York, N. Y.
Ealy, F. E., Salt River Valley Water Users' Assoc., Phoenix, Ariz.
Ehret, C. V., N. Y. Tel. Co., New York, N. Y.
Evans, E. R., Times Facsimile Corp., New York, N. Y.
Fauson, C. E., Clarke Elec. Co., Danville, Va.
Gleim, E. J., U. S. Bureau of Mines, Pittsburgh, Pa.
Gossland, R. D. (Mrs.), G. M. Giannini & Co., Inc., Pasadena, Calif.
Gropp, W. H., Myron C. Gould Assoc., San Francisco, Calif.
Grubb, A. W., Vinton, Iowa
Gusrae, G. B., Voorhees Walker Foley & Smith, New York, N. Y.
Hansen, H. C. I., Laur. Knudsen Mekanisk Etablissement, Copenhagen, Denmark
Harrell, W. F., Myron C. Gould Assoc., San Francisco, Calif.
Harris, V., Johns Hopkins Univ., Silver Spring, Md.
Haydon, J. C., Roane Anderson Co., Oak Ridge, Tenn.
Hill, W. L., Pacific Gas & Elec. Co., Sacramento, Calif.
Horsfall, R. T., The Dingle-Clark Co., Cleveland, Ohio
Hoyt, G. A., General Elec. Co., Schenectady, N. Y.
Janssen, W. H., General Elec. Co., Schenectady, N. Y.
Kramer, M. J., Aluminum Co. of America, Massena, N. Y.
Lane, J. W., Danville Tech. Inst., Danville, Va.
Nervig, I. L., T. I. P. Rural Elec. Co-operative Brooklyn, Iowa
Nevitt, H. J. B., Ericsson Tel. Sales Corp., New York, N. Y.
Osborn, J. F., General Elec. Co., San Francisco, Calif.
Peers, G. A., Pacific Gas & Elec. Co., Fresno, Calif.
Randall, R. D., Stewart-Warner Corp., Indianapolis, Ind.
Reed, T. M., The Ohio Public Service Co., Ashland, Ohio
Ross, B. R., General Elec. Co., Schenectady, N. Y.
Schiffbauer, W. F., Central Power & Light Co., Victoria, Tex.
Shoupp, W. E., Westinghouse Research Labs., E. Pittsburgh, Pa.
Sigler, I. B., Sigler, Clark & Winston, Weslaco, Tex.
Stathas, P. P., Duff & Phelps, Chicago, Ill.
Suri, G. D., E. S. D. (Machinery), Kankinara, West Bengal, India
Waggoner, E. M., Frederick Hart & Co., Inc., Poughkeepsie, N. Y.
Wehe, H. G., Bell Tel. Labs., New York, N. Y.
Whitehead, M., Bell Tel. Labs., Inc., New York, N. Y.
Wilson, G. W., General Elec. Co., Erie, Pa.

43 to grade of Member

To Grade of Associate

United States, Canada, Mexico, and Puerto Rico

1. North Eastern

Allard, G. A., General Elec. Co., Schenectady, N. Y.
Bristol, T. R., General Elec. Co., Schenectady, N. Y.
Bruns, J. H., Jr., Corning Glass Works, Corning, N. Y.
Bryson, J. O., General Elec. Co., Schenectady, N. Y.
Carlon, S. R., General Elec. Corp., Pittsfield, Mass.
Carter, W. F., General Elec. Co., Schenectady, N. Y.
Chausse, B. P., General Elec. Co., Schenectady, N. Y.
Clute, W. B., General Elec. Co., Schenectady, N. Y.
Coevering, J. V., Jr., General Elec. Co., Schenectady, N. Y.
Cypser, R. J., Mass. Inst. of Tech., Cambridge, Mass.
Day, J. H., Jr., General Elec. Co., Schenectady, N. Y.
Drastal, W. W., The Joslyn Co., Cortland, N. Y.
Farrell, W. M., N. Y. State Elec. & Gas Corp., Binghamton, N. Y.
Gaither, W. B., General Elec. Co., Pittsfield, Mass.
Gilson, W. J., Jr., General Elec. Co., Schenectady, N. Y.
Heising, C. R., General Elec. Co., Schenectady, N. Y.
Higginbotham, D. E., Mass. Inst. of Tech., Cambridge, Mass.
Hyldgaard-Jensen, L. A., General Elec. Co., Schenectady, N. Y.
Jellinek, E., General Elec. Co., Schenectady, N. Y.
Johnston, H. IV, General Elec. Co., Schenectady, N. Y.
Jones, H., General Elec. Go., Schenectady, N. Y.
Keith, W., General Elec. Co., Schenectady, N. Y.
Knapp, T. K., General Elec. Co., Schenectady, N. Y.
Lehr, S. N., General Elec. Co., Pittsfield, Mass.
Lesser, R. D., General Elec. Co., Schenectady, N. Y.
McGinley, M. M., General Elec. Corp., Schenectady, N. Y.
Mickiewicz, F. J., General Elec. Co., Schenectady, N. Y.
Miller, W. J., General Elec. Co., Lynn, Mass.
Moore, T. L., General Elec. Co., Schenectady, N. Y.
Morelli, T. J., General Elec. Co., Schenectady, N. Y.
Morton, W. R., General Elec. Co., Schenectady, N. Y.
Overby, J. G., General Elec. Co., Schenectady, N. Y.
Pearson, C. W., General Elec. Co., Schenectady, N. Y.
Petersen, M. L., General Elec. Co., Schenectady, N. Y.
Pindar, R. S., Jr., General Elec. Co., Pittsfield, Mass.
Reilly, T. J., American Steel & Wire Co., New Haven, Conn.
Ribb, S. S., General Elec. Co., Boston, Mass.
Segal, S., Federal Elec. Construction Co., Cambridge, Mass.
Sholund, V. J., Submarine Signal Co., Boston, Mass.
Skelton, D. B., General Elec. Co., Schenectady, N. Y.
Smith, R. C., Jr., General Elec. Co., Schenectady, N. Y.
Stevenson, K. M., Jr., General Elec. Co., Schenectady, N. Y.
Stukas, B. S., General Elec. Co., Schenectady, N. Y.
Taylor, R. S., General Elec. Co., Schenectady, N. Y.
Thomas, C. H., Harvard Univ., Cambridge, Mass.
Turner, W. H., Jr., General Elec. Co., Schenectady, N. Y.
Vincent, W. D., General Elec. Co., Schenectady, N. Y.
Vorderbrueggen, L. E., General Elec. Co., Schenectady, N. Y.
Woodbridge, L. P., General Elec. Co., Pittsfield, Mass.
Wuosmaa, L., General Elec. Co., Schenectady, N. Y.
Yungman, J. A., N. Y. Tel. Co., Albany, N. Y.

2. Middle Eastern

Abbott, LaV. L., Westinghouse Elec. Corp., Sharon, Pa.
Albert, E. A., Delco Products Div. of G. M. C., Dayton, Ohio
Allison, M. A., Jr., 343 South Powell Ave., Columbus, Ohio
Armstrong, W. C., Fuller Co., Catasauqua, Pa.
Barkley, J. C., Sun Shipbuilding & Drydock Co., Chester, Pa.
Blankenbeker, E. L., Heyl & Patterson, Inc., Pittsburgh, Pa.
Bowley, J. T., American Tel. & Tel., Philadelphia, Pa.
Brandon, A. K., Greenville Elec. Light & Power Co., Greenville, Ohio
Brodwin, M. E., Glenn L. Martin Co., Baltimore, Md.
Chapman, L. R., Jr., Natl. Advisory Comm. for Aeronautics, Cleveland, Ohio
Condon, J. F., Bureau of Ships, Navy Dept., Washington, D. C.
Crapo, H., Westinghouse Elec. Co., Lima, Ohio
Dawson, A. M., General Elec. Co., Johnstown, Pa.
DeIvernois, P. J., Jr., Union Switch & Signal Co., Swissvale, Pa.
Dickman, F. W., The M. D. Larkin Co., Dayton, Ohio

Diver, H. G., Wright-Patterson Air Force Base, Dayton, Ohio
Dummer, R. A., Pennsylvania Transformer Co., Canonsburg, Pa.
Fagin, I., Curtiss-Wright Corp., Columbus, Ohio
Faldetta, R. D., Natl. Advisory Comm. for Aeronautics, Cleveland, Ohio
Farmilo, H. S., Trumbull Elec. Co., Philadelphia, Pa.
Freienmuth, W. L., A. D. Ring & Co., Washington, D. C.
Glatz, H. J., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Haas, L. L., Air Materiel Command, Dayton, Ohio
Hobbs, J. E., Eastern Shore Public Service Co., Salisbury, Md.
Hunter, R. M., Rochester & Pittsburgh Coal Co., Indiana, Pa.
Kadetsky, J. M., Pennsylvania Elec. Co., Johnstown, Pa.
Kerdemann, A., Clark Controller Co., Cleveland, Ohio
Knock, C. N., Jr., The Rowan Controller Co., Baltimore, Md.
Lantz, A. D., Jr., Ohio Brass Co., Barberton, Ohio
Lewis, W. J. (re-election), The Ohio Brass Co., Mansfield, Ohio
Lively, J. P., 403 Security Bldg., Charleston, W. Va.
Martin, H. D., Metropolitan Edison Co., Easton, Pa.
Martt, E. C., General Elec. Co., E. Cleveland, Ohio
McBee, R. K., The Toledo Edison Co., Toledo, Ohio
McCracken, L. G., Jr., Penna. State College, State College, Pa.
McGlynn, J. R., General Elec. Co., Philadelphia, Pa.
Miller, J. L., Intl. Nickel Co., Huntington, W. Va.
Moore, W. L., Jr., Dept. of Army, Washington, D. C.
Morgan, G. F., Wheeling Elec. Co., Wheeling, W. Va.
Morgan, M. G., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Mosheim, M. E., Firestone Tire & Rubber Co., Pottstown, Pa.
North, C. R., Philadelphia Elec. Co., Philadelphia, Pa.
Oviatt, J. R., D. C. Oviatt & Co., Cleveland, Ohio
Piethe, G. H., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Portmann, P. A., Naval Research Labs., Washington, D. C.
Radus, S. L., Sidney Radus Elec. Co., Dayton, Ohio
Reynolds, J. P. (re-election), Air Materiel Command, Dayton, Ohio
Sagan, E. A. Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Songster, H. J., Philadelphia Elec. Co., Philadelphia, Pa.
Suderow, M. G., Goodyear Aircraft Corp., Akron, Ohio
Swing, F. A., Elec. Storage Battery Co., Philadelphia, Pa.
Teets, C. S., Jr., Bell Tel. of Pennsylvania, Philadelphia, Pa.
TenBroeck, K., Bethlehem Steel Co., Baltimore, Md.
Theibault, A. R., Wilkinson & Mawhinney, Washington, D. C.
Thompson, E. Y., Weller Mfg. Co., Easton, Pa.
Thorne, J. R., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Timberlake, A. J. T., The English Elec. Co., c/o Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Vallorani, A. A., Baldwin Locomotive Works, Eddystone, Pa.
Watson, W. R., Jr., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Weller, C. E., Weller Mfg. Co., Easton, Pa.
Whitehorne, R. A., America Tel. & Tel. Co., Washington, D. C.
Wicks, J. C., The Okonite Co., Philadelphia, Pa.
Williams, F. W., Williams Elec. Co., Towson, Md.

3. New York City

Ahlstrom, H. W., The J. G. White Engg. Corp., New York, N. Y.
Bower, L. C., Jr., Western Union Tel. Co., New York, N. Y.
Casey, K. T., Columbia Univ., New York, N. Y.
Chartoff, J., Sperry Products Inc., Hoboken, N. J.
Dhuy, R. L., Westinghouse Elec. Corp., New York, N. Y.
D'Italia, R., American Tel. & Tel. Co., New York, N. Y.
Ebersberger, J. J., Jr., Western Union Tel. Co., New York, N. Y.
Feldman, D., Newark College of Engg., Newark, N. J.
Gerry, M. E., 40-16—12th St., Long Island City, N. Y.
Hendrix, D. K., American Tel. & Tel. Co., New York, N. Y.
Huke, J. A., American Tel. & Tel. Co., New York, N. Y.
Jimenez, J. P., Intl. Business Machines Cork., San Juan, Puerto Rico
LaFiandra, P. J. (re-election), Veterans Administration, New York, N. Y.
Macomber, J. K., Arma Corp., Brooklyn, N. Y.
Phillips, T. L., New York Univ., New York, N. Y.
Rosenkranz, C. (re-election), Boys' High School (Annex), Brooklyn, N. Y.
Row, G. S., Polytechnic Inst., Brooklyn, N. Y.
Smith, R. D., Western Elec. Co., Hoboken, N. J.
Thompson, J. M., Watson Labs., Red Bank, N. J.
Tsagos, H. N. (re-election), Standard Oil Development Co., Elizabeth, N. J.
Wetherell, J. H., Sperry Gyroscope Co., Great Neck, N. Y.

4. Southern

Abernathy, T. W., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Anderson, W. H., Florida Power & Light Co., Delray Beach, Fla.
Bell, G. W., Florida Power & Light Co., Miami, Fla.
Botts, S. T., Jr., Kentucky Utilities Co., Tyrone, Ky.
Cain, C. H., Knoxville Utilities Board, Knoxville, Tenn.
Clarke, D. M., U. S. Atomic Energy Comm., Oak Ridge, Tenn.
Cochrane, W. O., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Cook, E. P., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Becnel, M. A., Jr., American Tel. & Tel. Co., Birmingham, Ala.
Durant, C. O., U. S. Atomic Energy Comm., Oak Ridge, Tenn.
Fink, W. R., Stone & Webster Corp., Baton Rouge, La.
Garrett, O. K., Atomic Energy Comm., Oak Ridge, Tenn.
Hardy, R. A., Carolina Chem. Corp., Nichols, Fla.
Harp, C. N., Cities Service Refining Corp., Lake Charles, La.
Harris, T. E., Jr., Southern Bell Tel. & Tel. Co., Chattanooga, Tenn.
Harrington, P. A., Gulf States Utilities Co., Lake Charles, La.
Heim, Ralph W., Reynolds, Smith & Hills, Jacksonville, Fla.
Hogle, C. R., Godat & Heft, New Orleans, La.
Holt, B. D., Duke Univ., Durham, N. C.
Johnson, L., Florida Power & Light Co., Cocoa, Fla.
Johnson, W. M., Atomic Energy Comm., Oak Ridge, Tenn.
Jones, A. E., Jr., Lower Colorado River Authority, Buchanan Dam, Tex.
Kerr, J., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
McFarland, V. C., Southwestern Gas & Elec. Co., Shreveport, La.
Meek, G. R., Westinghouse Elec. Corp., Roanoke, Va.
Nevitt, R. G., Electronic Labs., Inc., Louisville, Ky.
Newman, M., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Richard, R. F., Southern Gas & Elec. Co., Shreveport, La.
Stansberry, A. K., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Stepp, E. H., Island Creek Coal Co., Holden, W. Va.
Stulting, R. D., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Summer, C. F., Jr., Univ. of South Carolina, Columbia, S. C.
West, R. A., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Wood, L. R., Wilson & Toomer Fertilizer Co., Jacksonville, Fla.
Young, W. R., Raybro Elec. Supplies, Inc., Tampa, Fla.

5. Great Lakes

Anderson, A. M., Pepin Elec. Cooperative, Ellsworth, Wis.
Bateman, A. L., Jr., 2645 Pasadena Blvd., Wauwatosa, Wis.
Beecher, W. H., Firestone Tire & Rubber Co., Wyandotte, Mich.
Belot, E. H., Harley Davidson Co., Milwaukee, Wis.
Bender, R. E., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Boeke, A. C., Public Service Co. of No. Illinois, Maywood, Ill.
Deiss, E. A., Dow Chem. Co., Midland, Mich.
Dyson, A. A. R., Public Service Co. of No. Ill., Wheaton, Ill.
Elliott, L. F., Weltronic Co., Detroit, Mich.
Fetter, R. B., Indiana Univ., Bloomington, Ind.
Getsla, W. E., Western Elec. Co., Cicero, Ill.
Hally, H. G., Iowa Power & Light Co., Des Moines, Iowa
Haynes, D. C., Yates American Machine Co., Beloit, Wis.
Hedeen, P. M., Allis-Chalmers Mfg. Co., West Allis, Wis.
Henderson, P. T., Kuhlman Elec. Co., Bay City, Mich.
Herrick, R. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Hopwood, J. M. (re-election), Globe-Union Inc., Milwaukee, Wis.
Ifill, R. G., Allis-Chalmers Mfg. Co., West Allis, Wis.
Johnston, C. J., N. W. Bell Tel. Co., Des Moines, Iowa
Kittelson, T., Public Service Co. of No. Illinois, Maywood, Ill.
Malik, H. L., Continental X-Ray Corp., Chicago, Ill.
McMurray, R., Public Service Co. of Indiana, Indianapolis, Ind.
Patton, H. W., II, Board of Water & Light Commissioners, Lansing, Mich.
Rogers, A. M., Public Service Co. of No. Ill., Maywood, Ill.
Rosenthal, B. E. H., Guardian Elec. Mfg. Co., Chicago, Ill.
Scherr, E. F., Western Precipitation Corp., Chicago, Ill.
Simonsen, E. L., R. Cooper, Jr., Inc., Peoria, Ill.
Sloan, J. F., General Motors Corp., Saginaw, Mich.
Warner, J. M., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Woll, R. A., Westinghouse Elec. Corp., Chicago, Ill.

6. North Central

Bonness, Q. L., Univ. of Nebraska, Lincoln, Nebr.
Deutsch, K. T., U. S. Bureau of Reclamation, Denver, Colo.
Green, R. H., Colorado A. & M. College, Ft. Collins, Colo.
Miller, R. M., U. S. Bureau of Reclamation, Denver, Colo.
Peterson, S. E., Omaha Public Power Dist., Omaha, Nebr.

7. South West

Anderson, C. C., City of Austin, Austin, Tex.
Brandon, H. F., Jr., Arkansas Power & Light Co., Little Rock, Ark.
Broyles, R. E., Graybar Elec. Co., Corpus Christi, Tex.
Cheatham, F. L., Public Service Co. of Oklahoma, Tulsa, Okla.
Cockrell, B. D., Lower Colorado River Authority, Austin, Tex.
Conrad, P. A., Elec. Dept., Austin, Tex.
Doty, E. R., Union Elec. Co. of Mo., St. Louis, Mo.
Fowler, J. G., Southwestern Bell Tel. Co., Kansas City, Mo.
Hayden, L. B., Arkansas Power & Light Co., Littl Rock, Ark.
Kirk, B. M., Southwestern Bell Tel. Co., Corpus Christi, Tex.
Krause, N. L., Monsanto Chemical Co., St. Louis, Mo.
Lapham, N. A., The Univ. of Texas, Austin, Tex.
Matthews, R. K., W. N. Matthews Corp., St. Louis, Mo.
Nemec, S., Sverdrup & Parcel, St. Louis, Mo.
Nesbitt, W. B., Public Service Co. of Okla., Tulsa, Okla.
Ross, C., Jr., General Elec. Co., Dallas, Tex.
Schriver, W. L., Fagan Elec. Co., Little Rock, Ark.
Schroepfer, W. C., Jr., Southwestern Bell Tel. Co., Kansas City, Mo.
Singleton, L. C., Jr., Lower Colorado River Authority, Austin, Tex.
Somohano, G., T., Compania Electrica Newbery de Mexico, S. A., Mexico, Federal District, Mexico
Waggoner, R. S., U. S. Army Engrs., St. Louis, Mo.
Wrape, A. J., Jr., W. R. Wrape Stave Co., Little Rock, Ark.
Zumbrunn, J. E., Black & Veatch, Kansas City, Mo.

8. Pacific

Allen, L. P., California Water & Tel. Co., Monrovia, Calif.
Andersen, P. E., Weihe Frick & Kruse, c/o Manila Engg. Dist., A. P. O. 900, San Francisco, Calif.
Atkins, E. R., Jr., Union Oil Co. of Calif., Whittier, Calif.
Bonde, P. F., Dept. of Water & Power, Los Angeles, Calif.
Brown, J. T., Jr., Dept. of Water & Power, Los Angeles, Calif.
Burket, P. A., Pacific Tel. & Tel. Co., San Francisco, Calif.
Davies, Roy, City of San Francisco Municipal Railway, San Francisco, Calif.
Davis, R. J., Corbin & Davis Elec. Co., Phoenix, Ariz.
DeGuire, L. A., U. S. Bureau of Reclamation, Parker Dam, Calif.
Embry, M. O., Public Service Dept., Burbank, Calif.
Ferguson, N. D., California Elec. Works, San Diego, Calif.
Ferris, A. G., Public Service Dept., Burbank, Calif.
Giddings, E. V., Public Service Dept., Burbank, Calif.
Greenwood, W. F., Trumbull Elec. Mfg. Co., N. Hollywood, Calif.
Hoffman, H. M., Dept. of Water & Power, Los Angeles, Calif.
Holdridge, B. W., Central Ariz. Light & Power Co., Phoenix, Ariz.
Hurzeler, J. E., North American Aviation, Inc., Los Angeles, Calif.
Laton, B. C., U. S. Bureau of Reclamation, Fresno, Calif.
Martin, T. D., Pacific Gas & Elec. Co., Chico, Calif.
Nagle, F. I., Jr., Southern California Edison Co., Los Angeles, Calif.
Roach, D. F., Jr., Westinghouse Elec. Corp., San Francisco, Calif.
Swanson, R. W., Braun Mfg. Co., Alhambra, Calif.
Wagner, G. O., City of Burbank, Burbank, Calif.

9. North West

Eukes, F. L., Northern Pacific Railway Co., Livingston, Mont.
Gillmor, R. E., Portland General Elec. Co., Portland, Oreg.
Johnston, M. D., Puget Sound Power & Light Co., Chehalis, Wash.
Knight, D. H., Puget Sound Power & Light Co., Seattle, Wash.
McGaughy, J. V., General Elec. Co., Seattle, Wash.
Michel, H. A., General Elec. Co., Seattle, Wash.
Mitchell, J. R., Pacific Tel. & Tel. Co., Seattle, Wash.
Samsel, S. P., Portland General Elec. Co., Hillsboro, Oreg.

10. Canada

Costigan, A. W., St. Lawrence Paper Mills Co., Three Rivers, Quebec, Canada
Davison, H. E., Hydro-Elec. Power Comm., Toronto, Ontario, Canada
L'Homme, L. P., Southern Canada Power Co., Montreal, Quebec, Canada
MacDonald, G. L., English Elec. Co. of Canada, Montreal, Quebec, Canada
McGill, D. R., Canadian Utilities Ltd., Calgary, Alberta, Canada
Perron, J. L. L., Dominion Foils (Canada) Ltd., Cap-de-la-Madeleine, Quebec, Canada
Rooney, C. L., Abitibi Power & Paper Co., Ltd., Iroquois Falls, Ontario, Canada
Smith, G. A., St. Lawrence Paper Mills, Three Rivers, Quebec, Canada

Elsewhere

Charles, E. D., The County of London Elec. Supply Co., Ltd., London, England
Das Gupta, Aluminum Co. of India, Ltd., Burdwan, West Bengal, India
Ikdawi, S. A., North Delta Elec. Scheme, Boseile, Egypt
Mackley, K. W., Univ. of Melbourne, Melbourne, Australia
Molnar, H. J. E., Siemens-Schuckertwerke Ges. m. b. H., Vienna, Austria
Pool, W. J., British Thomson-Houston Co., Ltd., Rugby, Warwickshire, England
Santos, T. I. M., Compania Electric de Cuba, Havana, Cuba
Tsou, S. J., Chung-Yuan Paper Mfg., Shanghai, China

Total to grade of Associate
United States, Canada, Mexico, and Puerto Rico, 267
Elsewhere, 8

OF CURRENT INTEREST

IRE Annual National Convention Held in New York City, March 22-25

An attendance of more than 15,000 engineers and guests was reported for the annual national convention of the Institute of Radio Engineers which was held March 22–25, 1948, at the Hotel Commodore and the Grand Central Palace in New York, N. Y. Some 28 technical sessions during which more than 140 papers were presented highlighted the annual meeting.

WIDE RANGE OF TOPICS DISCUSSED

Technical papers on a wide range of subjects were discussed, including such topics as frequency modulation, networks, navigation aids, antennas, amplifiers, vacuum tubes, superregeneration, transmission, nucleonics, television, synthetic crystals, measurements, computers, wave propagation, microwaves, and circuits. Two symposiums, one on nuclear science and the other on advances significant to electronics, were special features of the meeting.

During the nuclear science symposium four papers were presented. L. R. Hafstad of the Research and Development Board, Washington, D. C., discussed "The Atomic Energy Problem and the Engineer." R. E. Lapp, of the same organization, discussed "The Program of the Atomic Energy Commission." "Electronic Problems of the Atomic Energy Program," were covered by J. B. H. Kuper, director of the electronics division of Brookhaven National Laboratory, Upton, N. Y. Finally, J. Z. Bowers, deputy director of biology and medicine, Atomic Energy Commission, Washington, D. C., spoke on "Biological Effects of Radiation and Consideration of Protection Problems." An interesting film, "Atomic Physics," was shown during the session. The motion picture covered some 140 years of development of atomic energy. It was reviewed in *ELECTRICAL ENGINEERING* last month (*EE, Apr '48, p 415*).

The symposium on advances significant to electronics included five papers. "Cybernetics," the capacity of the individual to assimilate and apply information, was discussed by N. Wiener, Massachusetts Institute of Technology, Cambridge, Mass. C. Shannon of the Bell Telephone Laboratories, Inc., Murray Hill, N. J., presented a paper called "Information Theory" which covered the limitations on transmission of information imposed by bandwidth, time, and signal-to-noise ratio. "Computer Theory" was presented by J. von Neumann, of the Institute for Advanced Study, Princeton, N. J. This paper treated the subject from the point of view of the philosophy of computers as a substitute for the brain in repetitive and original thinking processes. I. I. Rabi of Columbia University, New York, N. Y., discussed "Electronics and the Atom." Finally, The broad significance of the pulse type of modulation and its application to time-division of multichannel systems was covered in a paper called "Pulse Modulation," by E. M. Deloraine, International Telephone and Telegraph Corporation, New York, N. Y.

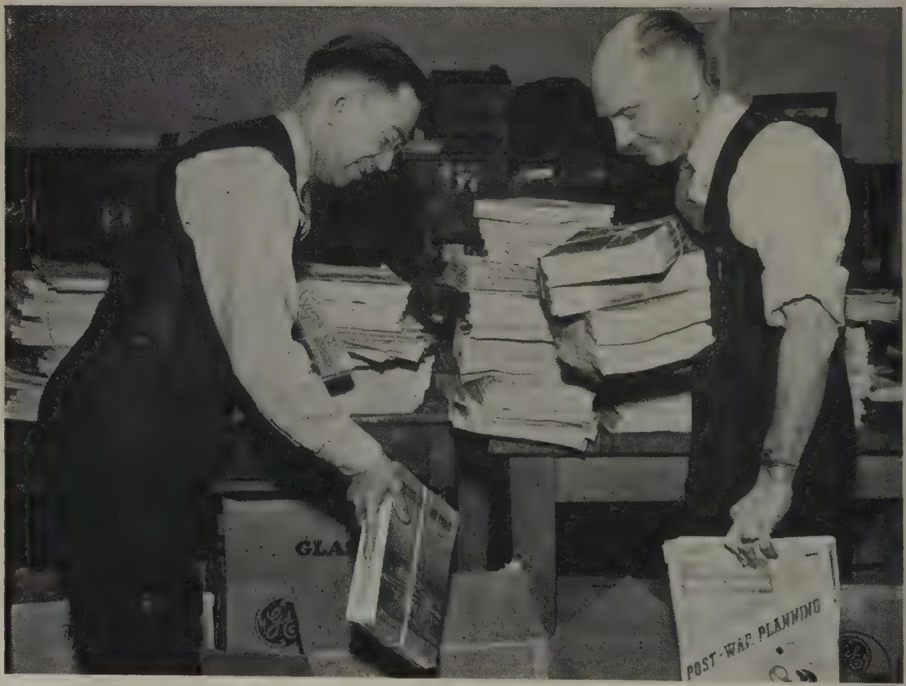
PRESIDENT'S LUNCHEON

A president's luncheon honoring President B. E. Shackelford was held in the grand ballroom of the Hotel Commodore on March 23, 1948. W. R. G. Baker, junior past president acted as toastmaster for the occasion. The principal speaker during the luncheon was W. Coy, chairman of the Federal Communications Commission. He discussed two main subjects: the progress the commission was making in reaching world-wide and regional agreements so that all nations can get the best use out of the radio spectrum, and the problem of making the best use of the ratio spectrum above 30 megacycles.

The World Telecommunications Conferences held at Atlantic City last summer were characterized by Mr. Coy as being the first great step to modernize our international procedures. He referred to the Provisional Frequency Board meeting in Geneva which is producing a draft of the first edition of the new international frequency list as agreed upon by at Atlantic City. It was mentioned that the "target date," when the new frequency assignments are to go into effect, has been set at September 1, 1949. A new permanent organization is to be created at Geneva to administer the new frequency list. It will be called the International Frequency Registration Board. It will determine on the basis of engineering principles whether particular frequency assignments would cause harmful interference to services already established. The changes in frequencies as listed in the proposed international frequency list do not affect the domestic broadcasting frequencies of the United States.

It also was mentioned that in order to make the fullest use of the frequencies above 30 megacycles, sound planning for the future was necessary. Many services already are competing for frequency allocations.

Publications for War-Torn Areas



As part of a nation-wide project to restock reference libraries in war-devastated areas around the world, engineers of the Kansas City Power and Light Company, Kansas City, Mo., at the suggestion of S. H. Pollock (M '36) assistant supervisor of the overhead department, assembled approximately 3,000 pounds of technical and engineering periodicals which were shipped to the American Book Center, Inc., Library of Congress, Washington, D. C. Here, Mr. Pollock (left) and F. P. Gilpin (A '30) are packing some of the collected publications for shipment. The project is sponsored nationally by the Engineers Joint Council

It is expected that dozens, perhaps even hundreds, of stations will be operating at the same frequency in different parts of the United States at these high frequencies. This will necessitate serious geographical restrictions on the geographical locations of stations, unless a relentless war is waged on spurious emissions and unwanted harmonic radiations. Engineers were urged to consider as incomplete any transmitter design that fails to include adequate provision for such suppression. Regarding receivers he pointed out that many present receivers are deficient in regard to the suppression of oscillator radiations and in selectivity.

ANNUAL BANQUET

The 36th anniversary banquet of the IRE was held March 24, 1948. Doctor W. L. Everitt of the University of Illinois acted as toastmaster for the evening. Doctor Shackelford, incoming IRE president, addressed the audience and then made a number of awards on behalf of the IRE. The 1948 medal of honor was presented to L. C. F. Horle, the Morris Liebmann Memorial prize was won by S. W. Seeley, and the Browder J. Thompson memorial prize was awarded to W. H. Huggins. Fellowship awards were conferred on some 26 men. Doctor W. R. G. Baker, the retiring president, addressed the gathering on "Radio-Electronic Frontiers." Doctor W. Jackson, of the Imperial College of Science and Technology in London, England, gave an amusing account of the impressions of a foreign visitor in New York City. M. Balcom, president of the Radio Manufacturers Association, discussed the close relationship that necessarily exists between the RMA and the IRE. In conclusion, Doctor A. N. Goldsmith and J. V. L. Hogan, two founders of IRE in 1912, recalled "Frontiers, Then and Now."

As in past years the radio engineering show at Grand Central Palace drew a large attendance. More than 190 exhibitors displayed the products of their companies, and the total value of the apparatus on display was valued at over $6,000,000. Prominent among the exhibits were those of the Army, Navy, and Air Force.

Research Fellowships Awards Announced by General Electric

Research fellowships amounting to $22,075 have been awarded by the General Electric educational fund to 16 graduate students for advanced study, according to a recent announcement. Seven of the students received the Charles A. Coffin Fellowships for advanced study in electricity, physics, and the physical sciences, while nine other students were awarded the Gerard Swope Fellowships for advanced study in industrial management, engineering, the physical sciences, and various scientific and industrial fields.

The fellowship awards are made annually to graduates of universities, colleges, and technical schools who have shown through previous work that they could undertake or continue advanced study either in the United States or abroad. Winners of the award may receive up to $1,500 plus a grant for any special equipment needed in their chosen field of research. Loans also may be available to the fellows during their period of study.

One of two winners who will receive awards to continue research already begun is Robert D. Teasdale (A '46) studying at the Illinois Institute of Technology, Chicago, through a previous grant of the Gerard Swope Fellowship.

Among members of the committee selecting the award winners were Roger I. Wilkinson (A '35) Bell Telephone Laboratories, New York, N. Y., and C. G. Suits (F '46) vice-president and director of research, and H. A. Winne (F '45) vice-president in charge of engineering policy, General Electric Company.

University of Louvain Asks Aid for Reconstruction

The AIEE board of directors has voted to place before the AIEE membership the following letter received from United Engineering Trustees, Inc., and directed to the secretaries of the Founder Societies:

> At the meeting of the board of trustees, held on September 25, President Perry read letters from the rector of the University of Louvain expressing appreciation for the help given to the university by the American engineers through United Engineering Trustees, Inc., after the war nearly 30 years ago. He asked further help at this time, when this five century old university, for the second time in 25 years suffered destruction from war. He asked this help principally for the restoration of the library, in the tower of which hang the bells, unharmed, given by the American engineers in 1928 as a memorial to the American engineers who gave their lives in the war. He asked this help for "one of the most painfully damaged private institutions of the world."
>
> The board of trustees received this plea with sympathy and directed that it be placed before the Founder Societies without comment.

Tenth Annual Awards Offered for Product Designs

The Gage Publishing Company, New York, N. Y., has announced the tenth annual *Electrical Manufacturing* product design awards, five cash purses totaling $2,500 being offered for the most interesting and realistic accounts of product development.

The competition is sponsored by the publishers to stimulate and encourage those engaged in product design and development and to accord appropriate recognition for outstanding achievement. A certificate of award also will be presented to successful contestants.

Entries now are being accepted and the closing date for the filing of manuscripts is June 30, 1948. The results of the competition will be announced in the tenth annual October product design number of *Electrical Manufacturing* where the award manuscripts will be featured.

Towle Named Acting Dean of Cooper Union Engineering

Professor Norman Lincoln Towle (M '24) head of the department of electrical engineering for the school of engineering, The Cooper Union, New York, N. Y., will be acting dean of the school of engineering following the recent death of Dean George F. Bateman.

Professor Towle is senior member of Cooper Union's school of engineering faculty, having been appointed instructor in electrical engineering in 1920. He has been professor and head of the electrical engineering department since 1932, and has done research in electrical engineering for the Bureau of Ships, United States Navy, and for the Westinghouse Electric Corporation. He is a graduate of Worcester Polytechnic Institute.

Buck Elected Radiomarine Head. Rear Admiral Walter Albert Buck, United States Navy (retired), former Paymaster General and Chief of the Bureau of Supplies and Accounts in the Department of the Navy, has been elected president of Radiomarine Corporation of America, according to a recent announcement. Voluntarily retiring on March 1, Admiral Buck ended a 30-year naval career. He had served as Paymaster General and Chief of the Bureau of Supplies and Accounts from October 1, 1946, to his retirement. For his wartime services, he was awarded the Legion of Merit and other honors.

INDUSTRY • • • • •

Radio-Telephone Toll Link Uses Multichannel Equipment

The Stromberg-Carlson Company, Rochester, N. Y., in collaboration with the General Telephone System, has established an experimental multichannel very-high-frequency radio-telephone toll link between Johnstown and Northville, N. Y. It is said to be one of the first multichannel installations of its kind in the independent telephone field. Two conversations may be carried on at the same time in the experimental equipment.

The radio link covers a 26-mile stretch over rugged Adirondack mountain country calling for careful selection of radio sites—a factor relatively unimportant in flat or rolling areas. At the Johnstown end of the circuit, both the transmitting and receiving antennas are mounted atop 40-foot cedar poles on a 970-foot hill. The Northville antennas, deeper in the mountains, are located on a 1,345-foot eminence. Here the transmitting antenna is erected on a 90-foot steel tower; the receiving antenna on a 65-foot cedar pole. The elevation of both ends of the radio link provides a direct line uninterrupted by hills or other obstacles lying between. Low-powered wide-band frequency-modulation transmitters were installed at each end.

Electron Diffraction Instrument Studies Surfaces and Thin Films

A new research tool has been designed to aid in the observation and measurement of surface conditions of metals, ceramics, and plastics according to a recent announcement of the General Electric Company. Called an electron diffraction instrument, it is used

High-Speed Electronic Computer

A new high-speed electronic computer developed by the servomechanisms laboratory of the Massachusetts Institute of Technology utilizes dozens of Sylvania germanium diodes in the maze of circuits on these panel units. The equipment, used to solve complex mathematical problems, will add, subtract, multiply, or divide five binary digits and announce the solution by means of neon lights

in the investigation of problems associated with corrosion, catalysts, lubricants, metallurgy, pigments, surface deposits, and graphite. It differs from the X-ray diffraction instrument, which analyzes thick specimens, in that the new instrument shows the crystal structure of surfaces and thin specimens up to 500 angstrom units.

To operate, a beam of electrons is directed at the specimen being tested, and any resulting diffraction pattern is photographed. The pattern consists of rings whose diameter, intensity, and orientation provide information for determining composition, orientation, and size of the crystals present.

The instrument consists of one unit containing vacuum chamber with specimen manipulator, visual and photographic recording camera, electron gun and beam focussing elements, regulated high-voltage power supply, and complete vacuum pumping equipment. The specimen chamber permits examination of specimens ranging from 0.1 to 4 inches in diameter. In many instances, the instrument will detect and help identify the very first chemical changes before they are visible under a microscope or are detectable by other means.

100,000-Kw Turbine Generator Serves New Jersey Company

A 100,000-kw 3,600-rpm turbine generator unit, the first machine of its size designed for 1,000 degrees Fahrenheit steam operation, has been put into full-scale service in Newark, N. J., at the Essex generating station of the Public Service Electric and Gas Company. Built by the General Electric Company, the machine is said to be the largest of its type in the world. It measures 77 feet in length and is 17 feet wide at its broadest point.

The turbine, with 19 stages in the high-pressure casing and five stages double-flow in the low-pressure section, was designed for steam conditions of 1,250-pounds-per-square-inch 1,000-degrees-Fahrenheit, 1.5-inch mercury absolute back pressure. It exhausts through 23-inch-long last-stage buckets of special warped design. The last-stage buckets, which operate at 1,390 feet per second, are mounted on a larger wheel than previously had been used on 3,600-rpm machines. The 1,390 rate is approximately ten per cent higher than previous 3,600-rpm machines were capable of attaining.

Mobile Gas Turbine Units Proposed for Emergencies

A long-standing need of power utilities and industry using power for a compact, easily moved, short-notice source of emergency electric current may be filled within the next few years by mobile gas turbine plants now under development by Allis-Chalmers engineers. Studies already have been made of 3,000- and 6,000-kw units to be mounted on railway trucks for rapid movement over normal railway track or comparatively irregular freight and utility yard tracks. The proposed units could operate as a sole source of power or could be synchronized with an existing power system.

The prime mover of the 3,000-kw unit operates on the simple gas turbine cycle with regenerator. With an inlet temperature of 1,300 degrees Fahrenheit, the unit would have a fuel-bus efficiency of about 23 per cent at full load. Mounted on eight carrying axles arranged in four standard freight car trucks, the power plant would weigh approximately 230,000 pounds. Sufficient oil-tank space is built into the unit to permit full load operation for at least six hours. The turbine unit is coupled to a 3,600-rpm generator through a reduction gear. All working air for the gas turbine plant and cooling air for the generator is taken in through filters in the side walls of the cab. All electric equipment and synchronizing apparatus is built into the cab.

General arrangement of the more powerful 6,000-kw 3,600-rpm unit is identical to the smaller power plant, except that the inlet temperature is 1,150 degrees Fahrenheit, and a gear will not be necessary.

OTHER SOCIETIES

AAAS Centennial Celebration to Be Held in September

With "One World of Science" as its central theme, the centennial celebration of the American Association for the Advancement of Science will be held in Washington, D. C., September 13–17, 1948. To emphasize the importance of the theme, a number of symposia on scientific subjects of great interest, not only to scientists, but also to the general public, is being organized.

Broad surveys of important sectors of science in relation to the future of mankind will be presented at the meeting. The papers in each symposium will be integrated about some subject having wide scientific interest, for example, world health problems; problems of the ocean, fuel, and power; genetics and the future; synthetic elements; nucleonics; problem of the ice ages; chemotherapeutics; man's self conflicts; wave motion. The major subjects will be selected so as to lend themselves to general treatment by scientists in various fields.

The AIEE will participate in sponsoring the centennial.

IRE to Convene on West Coast in Fall

The West Coast Convention of the Institute of Radio Engineers, the Institute's second postwar convention, will be held in conjunction with the West Coast Electronic Manufacturers' Convention, at the Biltmore Hotel, Los Angeles, Calif., September 30–October 3, 1948.

As this section of the United States is an active center of work in the varied fields of guided missiles, aircraft and rocket work, motion pictures, broadcasting, and other phases of a rapidly expanding electronics industry, papers will be presented covering the newer aspects of these activities. In addition, there will be a number of trips to

Southern California centers of interest, such as the famed telescopes in that vicinity.

Convention chairman for the IRE is Lloyd Sigmon, chief engineer of radio station *KMPC* in Los Angeles. John J. Fiske (A '42) Westinghouse Electric Corporation, Los Angeles, is vice-chairman.

ASRE Meeting. Nine technical papers on as many fields of refrigeration will be the feature of the 35th spring meeting of The American Society of Refrigerating Engineers to be held in Swampscott, Mass., May 31–June 2, 1948. The papers will include several on recent developments on heat transfer techniques, detailed description of the new "sniffer-type" refrigerant leak detector, and a paper on ultralow temperature installation. The Boston section of the society will act as host for the occasion.

RWMA Announces Contest for Resistance Welding Papers

Announcement has been made of cash prizes to be awarded in 1948 by the Resistance Welder Manufacturers' Association for outstanding papers dealing with resistance welding subjects. The total amount of the awards is $2,000, and a wide choice in subject matter is allowed to assure eligibility to all papers which cover worth while and significant achievements in the field. The contest judges will be appointed by the American Welding Society, and awards will be made at the 1948 Fall meeting of that society.

The contest is open to anyone in the United States, its possessions, and Canada, and to any member of the American Welding Society from any place in the world. To be eligible for the contest, all entries must be received at the headquarters of the American Welding Society, 33 West 39th Street, New York 18, N. Y., not later than July 31, 1948.

Complete contest rules and list of prizes may be obtained from the Resistance Welder Manufacturers' Association, 505 Arch Street, Philadelphia 6, Pa.

Engineering Progress Show. The second annual Engineering Progress Show will open on Tuesday, May 11, at the Franklin Institute in Philadelphia. At the show, which is sponsored by the Engineers' Club of Philadelphia Juniors and the Franklin Institute of Pennsylvania, industrial corporations from all parts of the United States will submit to the public their latest advancements in the engineering fields, and, in addition to the varied scientific and industrial exhibits, prominent engineers will be present at the evening sessions to speak on subjects of interest to engineers and to the technically minded public.

Future Meetings of Other Societes

American Iron and Steel Institute. May 26–27, 1948, New York, N. Y.

American Management Association. Production conference, May 13–14, 1948, Chicago, Ill.

American Society for Engineering Education. June 14–18, 1948, Austin, Tex.

American Society for Testing Materials. Annual meeting, June 21–25, 1948, Detroit, Mich.

American Society of Agricultural Engineers. Annual meeting, June 20–23, 1948, Portland, Oreg.

American Society of Civil Engineers. Summer convention, July 21–23, 1948, Seattle, Wash.

Canadian Association of Physicists. Third annual congress, May 26–29, 1948, Ottawa, Ontario, Canada.

CIGRE (International Conference on Large Electric High-Tension Systems) Biennial meeting, June 24–July 3, 1948, Paris, France.

Edison Electric Institute. Annual engineering meetings, May 3–5, 1948, Chicago, Ill.; annual convention, June 2–4, 1948, Atlantic City, N. J.

Fluorescent Lighting Association. Show, June 6–10, 1948, New York, N. Y.

Institute of Radio Engineers. Pacific Coast convention, September 30–October 2, 1948, Los Angeles, Calif.

National Association of Broadcasters. 26th annual convention, week of May 17, 1948, Los Angeles, Calif.

National District Heating Association. 39th annual meeting, May 18–21, 1948, St. Louis, Mo.

National Electrical Wholesalers Association. 39th annual convention, May 2–7, 1948, Buffalo, N. Y.

Pennsylvania Electric Association. Prime movers committee meeting, June 10–11, 1948, Scranton, Pa.

Pittsburgh International Conference on Surface Reactions. June 7–11, 1948, Pittsburgh, Pa.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electrical Essay

To the Editor:

J. Slepian's answer to his electrical essay on the direction which a diamagnetic body will take brings up the interesting fact that most textbooks disagree with his statements. These texts state that the rod, if placed in the field of a magnet, will align itself at right angles and they are backed up by Faraday who actually did it ("Experimental Researches," volume 3, number 2296—"When this (bismuth) bar was suspended in the magnetic field . . . it pointed freely in the equatorial direction"). Where these texts go astray is in not realizing that Faraday's field was not uniform, and that this alters the behavior. (Doctor Slepian was careful to mention a uniform field in his problem.)

Two other texts, which work out the torque on an ellipsoid in a uniform field, point out the fact that the direction of the torque comes out the same whether the material is paramagnetic or diamagnetic. These are Smythe's "Static and Dynamic Electricity," and Stratton's "Electromagnetic Theory."

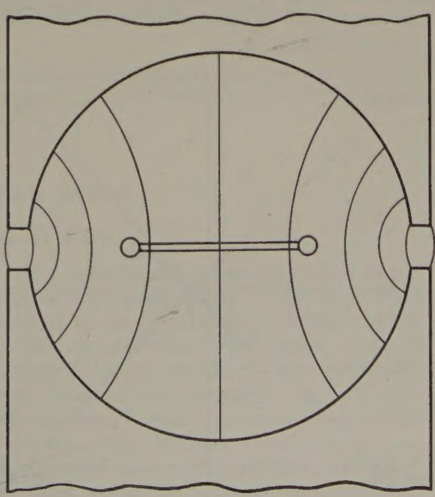


Figure 1

Faraday made other tests with bismuth and arrived at a simple and general law which accounts for the behavior, "The ruling principle that each particle tends to go by the nearest course from strong to weaker points of magnetic force." If we idealize our rod into two bits of magnetic matter at each end of a thin rod of neutral material, then each bit of matter finds itself in an initial (external) field plus a secondary field set up by the induced magnetization of the other particle. If the initial field is uniform, the particle can move only because of the nonuniformity of the secondary field and this always will cause it to move so as to line up with the initial field. If the initial field is nonuniform, this easily may swallow up the effects of the secondary field. In Faraday's case the field diverged as it left the pole and the bismuth bar moved to points of weak field, which meant it had to turn at right angles.

This suggests that it also should be possible to get a paramagnetic bar to turn at right angles by using a suitably nonuniform field which converges as it leaves the pole faces. Such a field is shown in Figure 1 of this letter. This effect should be accentuated if the rod is made with two "knobs" on the ends and the central part very thin, for then the secondary field is due to material at a large distance and will be relatively unimportant.

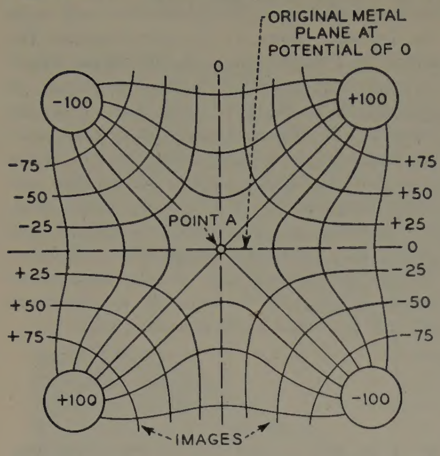
BERNARD LITMAN (A '42)

(715 Fairmount Place, New York, N. Y.)

To the Editor:

On page 58 of the January 1948 issue of *ELECTRICAL ENGINEERING*, J. Slepian in his reply to his electrical essay published in the September 1947 issue (*p 872*), illustrates a special case to prove that a line of

Figure 1



force is not always perpendicular to the smooth surface of a conductor at the point where they meet.

If the conducting plane in his illustration is replaced by the suitable image sources, as indicated in Figure 1 of this letter, it is noticed that point A is a saddle point in the plot of the potential field, and hence has potential gradient of zero.

A line of force usually is defined as the line along which a massless negatively charged particle would move if it were placed in the field, and its presence did not alter the field. At any point, the line of force coincides with the potential gradient.

If the definition is adhered to, there is no line of force at the point A, as a charged particle placed at A would not move. Hence, no line of force exists which is not perpendicular to the conducting surfaces at the meeting point.

MARTIN GRAHAM

(Student at the graduate school of Harvard University, Cambridge, Mass.)

To the Editor:

The answer given in the January 1948 issue of *ELECTRICAL ENGINEERING* to question 1 of J. Slepian's September electrical essay is incorrect. The statement is true.

In order that the intersecting planes be equipotentials while in the vicinity of charged bodies a nonuniform distribution of charge on the surfaces of the planes is essential. If Mr. Slepian will examine the quantitative values of this charge he will find that it decreases as the intersection of the planes is approached and is zero at the intersection. No electrostatic lines of force terminate at the intersection and the paradox suggested by Mr. Slepian disappears.

T. W. MOUAT (M '45)

(Department of physics, University of British Columbia, Vancouver, British Columbia, Canada)

To the Editor:

In reference to page 58 of the January issue of *ELECTRICAL ENGINEERING*, I would like to question the solution to question 1 of the essays published in September 1947.

The author starts with the statement "In an electrical field, a line of force *meeting* the smooth surface of a conductor is always perpendicular to the surface. True or false?"

He based his argument, and I quote in part: "Such a line of force *approaching* A makes an angle of 45 degrees with the plane." In his argument he makes no statement about the line meeting the plane. This type of argument leads him to what I believe is a false answer to the original question. I believe the correct answer is that at point A the field intensity is 0, therefore, there will be no line of force at A.

If it is desirable to carry the argument further, it seems to me that the best method of solving such a problem is to replace the zero equipotential plate in the figure with images of the cylinders. Using such a diagram, the symmetry of the charged conductors would tell us without any actual calculation that the field intensity at A will be 0. If we wish to calculate the field intensity at a point an infinitely small distance to the right of A and in the zero equipotential surface, we would get a resultant field intensity at this point with a small vertical component down. I have drawn in the various field intensities on Figure 1 of this letter showing their direction. It will be noticed that the field intensity E_c and E_b are equal in magnitude and are slightly greater in magnitude than E_a and E_d. E_a and E_d, of course, are also equal in magnitude. The net result, as I have stated, is a small resultant value perpendicular to the plane surface and in a down direction. A similar discussion will show that a point to the left will give a resultant perpendicular to the plane surface but up.

I thoroughly enjoy the electrical essays appearing in *ELECTRICAL ENGINEERING* and hope we will have many more. I find the students also have considerable interest in this feature. It is particularly because of this student interest that I feel that we must be very careful in stating the electrical essays and in giving the answers. The very nature of the electrical essay requires that the statement of the problem in the essay be clear. Otherwise, the essays are meaningless, or, at best, open to argument. It is in this respect that I would like to comment upon the electrical essay appearing in the January issue.

The author's question is: "Is the reasoning true or false?" In reading the essay I personally could not find the author's reasoning. I found rather a statement of the problem and a conclusion. It would seem impossible to state whether the reasoning is true or false unless the author does show his line of reasoning with regard to his conclusion. With the proper assumptions, I believe I could arrive at the stated answer with no error in my reasoning. However, I presume the author means to imply that his reasoning is false because in the answer as stated he considered the current around the coil which would give the flux field as indicated in his diagram, but neglected to take into account the fact that the coil is advancing along the cylinder from left to right. This, of course, will give the equivalent of one conductor carrying current from left to right. In most problems, the error introduced by neglecting this factor is smaller than the error made in reading the electric instruments. It then would be good engineering to neglect this factor and the author could be commended for this line of reasoning. If he feels that this cannot properly be neglected, would he be justified in ignoring the earth's magnetic field or the field due to the current in the wires leading to the coil about which the problem as stated gives no information?

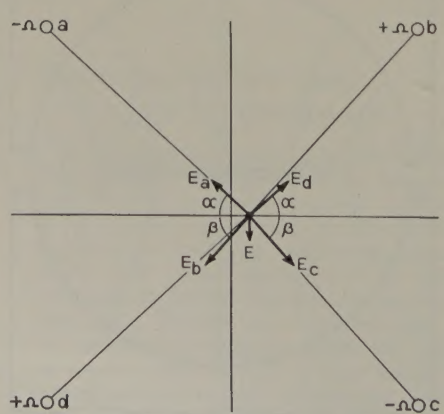


Figure 1

It is my contention that, as the author does not show his reasoning in proper detail, and furthermore as he makes no statement of the degree of accuracy wanted in his statement of the problem, the essay in the January issue is not stated in such a way as to warrant a true-false answer to the question "Is the reasoning true or false?" Or have I failed completely to understand the essay?

WILLIAM H. GAMBLE (M '33)

(Head, electrical engineering department, South Dakota State College, Brookings, S. Dak.)

Voltage Notation Conventions

To the Editor:

Dean Lewis and Professor Reed have done a good job in their paper "Voltage Notation Conventions," in clarifying a situation which is probably responsible for more fruitless arguments than any other single thing in electrical engineering. But how did it ever happen that the distinguished scientists who gave us our basic concepts got into such a state of confusion? There must be a villain lurking somewhere among the shadows in this play.

In my opinion he is a Jekyll and Hyde character who at some times signs his name with the initial E and at other times with the initial V, but his real name is "electromotive force." He is a most inconsistent and illogical fellow who goes about popping up here and there under various aliases, being very difficult to apprehend because his given name conceals his real identity.

The very idea of an electromotive force is inconsistent with our accepted concept of a difference of potential. The concept of a force involves action at a single point in a definite direction. Hence force is a vector quantity. But the concept of a potential difference involves differences in the state of compression at two separate points. It is not a vector quantity except in the very special case of sinusoidal variations with respect to time.

While this culprit named electromotive force may have done some useful things in his early days, his 2-faced nature has been exposed gradually and he now is becoming an outcast. Let us proceed to condemn

him and be rid of this objectionable character.

If this were done we could go one step further than is proposed in this article. We then could abandon the confusing practice of writing the same quantity into a given equation under two different names. Our second Kirchoff's law equations then would be written entirely in terms of potential differences. They would be either all E's or all V's, no matter which; but both the E and the V never would appear in the same equation. We then would have a single standard of voltage based upon the energy level of one point above another instead of our confusing double standard of electromotive forces and impedance drops which originated in the illogical concept that a voltage and a force were quantities having the same physical nature.

L. E. BECK (M '37)

(Associate professor of electrical engineering, Purdue University, Lafayette, Ind.)

To the Editor:

The need for standardization on a single double-subscript convention is well brought out in the article by Reed and Lewis and the recommended choice is a logical one.

I prefer to think of the double-subscript convention, or a reference direction arrow, or the use of + sign, or polarity marks, as establishing a reference positive direction for the measurement voltage magnitude and polarity, rather than as fixing an "assumed positive polarity." Having established the direction in which positive polarities are measured, the sign of the quantity determines the polarity of each point, without the stigma of having made a bad assumption and later correcting it.

It is worthy of note that use of convention II*A*, as recommended by the authors, does not require thinking of voltages as drops. One can read the symbol E_{an} either as "the voltage of *a* above *n*" or as "the voltage drop from *a* to *n*." As these quantities are identical, either point of view can be used without changing any of the symbols or numerical values in the slightest.

In connection with the recommendations to ASA, I can see no need for the final clause in recommendation 1, namely; "independently of whether the current is increasing or decreasing." I would suggest its deletion.

Consistent with the idea that it is only the reference positive direction that arbitarily is assumed, I would change the end of recommendation 4 to read "the current is in the positive direction," rather than "the current is in the direction assumed." The current has not been assumed in any direction; it is only the positive direction that has been fixed.

Also, consistent with the same notion, recommendation 5 would need to be reworded slightly. The following is suggested.

The double subscripts on *any* voltage symbol should designate that the positive direction for measuring voltage rise is from the second subscript to the first.

Also, in recommendation 6:

Positive numerical value of a voltage indicates that it is in the assumed positive direction.

In connection with the suggested + polarity marks for voltage, this is merely an alternate to an arrow. The arrow head indicates as well as the polarity mark which is the reference positive direction. The arrow serves the further purpose of designating, for sure, between which two points the voltage in question is measured. The only other apparent way to accomplish this with a single subscript (or no subscript) is by a double-ended arrow, as in Figure 2*A* of the article, plus a polarity mark, except in the rather special case, Figure 3, where the points are adjacent so that no uncertainty arises. I believe this usage is too special to warrant standardizing. Much work with single or no subscripts could not be converted to this form. The method should be considered as an alternate to the use of voltage arrows.

While standardization will be of great future value, this article emphasizes the need for teaching not only a method, but the essentials of *any* logical method so that the student readily can adapt himself to the various systems used by different authors. The essentials are simple. To specify without question the magnitude and direction of a voltage and current, one must adopt a convention as to which direction is positive and give the magnitude, with appropriate sign or vector position in that direction. In the case of d-c or instantaneous value quantities, this determines the voltage completely. In the case of vector quantities, it determines the magnitude and the relative phase of the quantities all taken in the reference positive direction. It does not, of course, fix their actual instantaneous values until a further convention has been adopted relating the instantaneous value mathematically to the vector.

I would like to raise the question as to whether the defining relationship,

$$e = R\sqrt{2}Ee^{j\omega t}$$

is in sufficiently common use that it might be standardized as the relation between a vector E and the instantaneous voltage e which it represents, or between I and i, and so forth.

All of the recommended rules in the article read as though instantaneous values were in mind, whereas the examples are partly vector quantities. An implication exists that there is a single transformation by which one gets from vectors to instantaneous values. It might help if this transformation were standardized also.

E. L. HARDER (M '41)

(Consulting transmission engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa.)

Flow Meter

To the Editor:

In a letter to the editor, published in the March 1948 issue of *ELECTRICAL ENGINEERING* (*p 311*), George Keinath refers to the electrocaloric flow meter which I described in an article in the December 1947 issue of this magazine (*pp 1216–19*). He compares it with a gas flow meter which Professor Carl Thomas described in *Iron Age* in 1911 and which measured the flow of gases only by exposing an elaborate arrangement of heater coils and resistance thermometers to the gas flowing within the gas line.

While Mr. Keinath in his letter admits three important differences between the Thomas gas meter and the flow meter described in my article, he completely overlooks the following features which are fundamental and make the latter a practical instrument for the measurement of liquids as well as gases.

In the instrument described in my article, all measuring elements are arranged on the outside of the fluid line by winding the heater coil as well as the resistance thermometers on the outside wall of heat insulated sections of the conduit. This results in the advantage that corrosive, inflammable or explosive fluids can be measured safely and accurately as there is no contact between the fluid and the measuring elements. The heat transfer takes place through the walls of the conduit. Temperature compensation is an absolute must in an arrangement of this type if liquids are to be measured whose specific heat and viscosity varies appreciably with temperature. Without the temperature compensation described in my article, a very large temperature error would result and make the instrument totally impractical.

Furthermore, it is by the use of the highly sensitive electronic control and of the bypass arrangement for large rates of flow that it becomes possible to build the instrument with a low wattage heater coil of small mass and to obtain the small time lag which is required, particularly for automatic control without hunting. As mentioned in my article, the maximum input of 50 watts to the heater coil is ample, for instance, for the measurement of 2,000 pounds of gasoline per hour. By contrast Professor Thomas used 1,150 watts in his directly exposed heater element to produce a temperature rise of only about two degrees Fahrenheit.

Additional distinguishing features can be pointed out, but the foregoing must suffice in this brief communication to correct Mr. Keinath's statements.

J. H. LAUB (M '36)

(Assistant to the president, Charles Engelhard, Inc., East Newark, N. J.)

Phase Transformer

To the Editor:

This is a reply to G. B. Winther's letter which appeared in the March issue of *ELECTRICAL ENGINEERING* (*pp 311–12*).

It is true, as Mr. Winther points out, that a perfectly good phase transformer can be made by using the polyphase stator windings of an induction motor as the transformer primary, and using a wound rotor winding, with the rotor stationary, as the secondary. If the rotor is pressed in tightly, so that there is no air gap, the motor becomes a better transformer than an ordinary motor would be.

However, it is not possible to obtain frequency transformation with such a stationary machine. This easily may be seen by the following analysis.

Applying polyphase 60-cycle voltages across the stator windings, with the rotor windings open, produces a revolving

magnetic field, varying at 60-cycle frequency in both rotor and stator. If the rotor winding has the same number of poles as the stator, 60-cycle voltages also will appear across the rotor terminals. If the rotor winding has a different number of poles from the stator, the span of each rotor coil will be fractional with respect to the pitch of the magnetic flux, and the voltages across the secondary winding terminals will be reduced by the pitch and distribution factors of the rotor winding.

In this instance also, if the rotor winding has two or more circuits in parallel, the voltages induced in the separate circuits normally will not be in time phase, so that circulating currents will flow inside the windings; further reducing the voltages that appear across the terminals. In the limiting case, with all the rotor coils in series, there will be no voltage across the rotor terminals, and the rotor winding will behave as an open circuit. If all the rotor coils are in parallel, they will form a short-circuit "squirrel cage," and there still will be no voltage across the rotor terminals.

It is clear that all the flux that the stator produces has the same frequency as the applied voltage, and the same is true of all the voltages induced by this flux in the rotor winding. The only way that the frequency can be changed is by the rotation of one winding with respect to the other, neglecting the small triple frequency voltages produced when there is magnetic saturation; or by employing resonant circuits with capacitance for energy storage.

PHILIP L. ALGER (F '30)

(Staff assistant to manager of engineering, General Electric Company, Schenectady, N. Y.)

NEW BOOKS • • • • •

"Computing Mechanisms and Linkages." Based upon wartime development, this is the 27th volume of the radiation laboratory series sponsored by the Massachusetts Institute of Technology, Cambridge, Mass. Technique, rather than theory, is emphasized, with various types of bar-linkage computers being stressed. Fundamental concepts and basic design problems are detailed before the author progresses to the more advanced aspects of computer design. Illustrations include numerous nomographs as well as drawings of the linkages. By Antonín Svoboda. McGraw-Hill Book Company, New York, N. Y., 1948, 359 pages, $6^1/_4$ by $9^1/_4$ inches, $4.50.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

SEQUENTIAL ANALYSIS. By A. Wald. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 212 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $4. A full discussion is offered of the new statistical technique known as the Sequential Probability Ratio Test. The author explains the fundamental theory, the applications, and potentialities of this method of analysis. Comparison with other procedures is made, and through a discussion of possible approaches to problems a groundwork is provided for further research.

FILING AND INDEXING, A STUDY OF THE PRINCIPLES AND PRACTICE OF CLASSIFICATION AS APPLIED TO FILING SYSTEMS. O. W. Roskill and Company (Reports) Ltd., London, England, 1946. 169 pages plus appendixes, 8 pages, tables, 14 by 9 inches, paper, £2, 2s. Following a brief discussion of the purpose of filing, this useful study presents simple methods of classification by name or subject including cross-reference arrangements. Information also is given on the physical equipment for filing, and on the management of files.

RADAR SYSTEM ENGINEERING, edited by L. N. Ridenour. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 748 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $7.50. Volume 1 of the Radiation Laboratory series, this new book outlines the general principles of design of radar systems. It is intended as a basic treatise and reference work for any one interested in making any application of radar.

TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS FOUR, FIVE, AND SIX (Annals of the Computation Laboratory of Harvard University, volume 5). TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS SEVEN, EIGHT, AND NINE (Annals of the Computation Laboratory of Harvard University, volume 6). By the staff of the computation laboratory of Harvard University. Harvard University Press, Cambridge, Mass., 1947, no pagination, tables, 11 by 8 inches, cloth, $10 each. Continuing the annals of the computation laboratory of Harvard University, volumes 5 and 6 contain 10-place tables of the Bessel functions of the first orders $[J_n(X)]$ for n equal to four, five, and six, and for n equal to seven, eight, and nine. A description of the techniques employed may be found in volume 3 of this series. Included in volume 5 is a method of interpolating in the tables by means of the Taylor expansion.

TECHNICAL DRAWING PROBLEMS. By F. E. Giesecke, A. Mitchell, H. C. Spencer. Second edition Macmillan Company, New York, N. Y., 1947. 9 pages text, 105 sheets of diagrams, 11 by $9^1/_4$ inches, paper, ring binder, $2.75. Containing problems which are designed to cover the important fundamental principles of technical drawing, this volume is not intended for use as a complete course in itself. Following a section on the use of instruments is one on the geometry of technical drawing. Succeeding sections discuss the construction of letters and numbers, problems on views, identification, revolutions isometric and oblique drawing, and dimensioning. Problems on fasteners and springs complete the book.

TEXTBOOK OF THE MATERIALS OF ENGINEERING. By H. F. Moore and others. Seventh edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 500 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5. Elementary in character, this book is devoted to the common materials used in structures and machines, together with brief descriptions of their manufacture and fabrication. The revised edition covers many new materials of construction, developed during the war, and new methods of processing them. Additional data on plastics, synthetic rubber, testing machines, and methods have been included.

WIND-TUNNEL TESTING. By A. Pope. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 319 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $5. This volume presents an analysis and study of the extensive but scattered technical information published on the subject. The topics covered are design and general consideration of tunnels, testing procedures with scale-model aircraft, extrapolation to full scale, and wind-tunnel-boundary corrections. The design of a propeller-flow straightener system is treated. An appendix discusses the construction of a wind-tunnel model. A list of references is given at the end of each chapter.

WIRELESS DIRECTION FINDING. By R. Keen. Fourth edition. "Wireless World" by Iliffe and Sons, Ltd., London, Birmingham, Coventry, and Manchester England, and Glasgow, Scotland, 1947. 1,059 pages, illustrations, diagrams, charts, maps, tables, 8 by 5 inches, cloth, 45s. Revised to include material on research work done during the war, this volume is intended for use as a manual, not a textbook. A comprehensive bibliography of more than 700 items covers the literature on directive reception and transmission as applied to navigation taken from 75 magazines within the period 1893–1947.

INVENTIONS, PATENTS, AND MONOPOLY. By P. Meinhardt, with a foreword by J. Mould. Stevens and Sons, Ltd., London, England, 1946. 352 pages, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, 25s. Containing concise information concerning British patent law practice and procedure, this volume is divided into four parts. Part 1 is concerned with the characteristics of inventors and inventions; Part 2 the major portion of the volume, with a concise description of the law and practice. Part 3 is concerned with abuse of patent monopoly; and part 4 with suggestions for reform.

PRACTICAL THEORY OF MECHANISMS. By P. Grodzinski. Emmott and Company, Ltd., 31 King Street, West, Manchester, England, 1947. 166 pages, diagrams, charts, tables, $6^3/_4$ by 4 inches, cloth, 7s.6d. Presenting an introduction to the basic principles of the theory of mechanisms, this book endeavors to make the reader realize the value of these ideas in dealing with all engineering problems. The book is a revised and enlarged translation of the author's "Angewandte Getriebelehre."

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

The Exhaust-Water Spray Fire Protective System for Wellways. A 16-page booklet which describes in detail this new method of combating the spread of fire and fumes through burning buildings has been published jointly by Otis Elevator Company, Westinghouse Electric Corporation, and Grinnell Company, Inc. The three firms co-operated in developing the technique, using an exhaust system and curtain of water, and in staging demonstrations this past year before fire prevention experts, construction engineers, department store executives, fire chiefs, and municipal building authorities. Copies of the booklet are available on request from the Otis Elevator Company, 260 11th Avenue, New York 1, N. Y.

Safety for the Household. The principal hazards to safety in the home, and the means for eliminating or reducing them are discussed in the 200-page edition of this booklet now available from the Government Printing Office as National Bureau of Standards Circular 463. It may be obtained from the Superintendent of Documents, Washington 25, D. C., at a cost of 75 cents per copy.

Three-Channel Carrier Telephone. Lenkurt Type 32 carrier telephone systems are described in Bulletin 62A. An engineering report on the system, the 68-page bulletin covers frequency allocations for carrier telephone, and continues with descriptions of the terminals, repeaters, pilot regulators, and auxiliary units which make up the system. Available from the Lenkurt Electric Company, 1101 County Road, San Carlos, Calif.

Water Cooler Story. A brief booklet issued by members of the Drinking Water Cooler Manufacturers Association, a division of the Refrigeration Equipment Manufacturers Association, has as its theme "better water for better living." Available from the Drinking Water Cooler Manufacturers Association, 1107 Clark Building, Pittsburgh 22, Pa.